U. S. Department of Energy
Federal Energy Technology Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

We Solve National Energy and Environmental Problems

September 15, 1997

Program Research and Development Announcement for **"Global Climate Change - Novel Concepts For Management of Greenhouse Gases,"** PRDA No. DE-RA26-98FT35008

Prospective Offerors:

The purpose of this executive summary letter is to highlight salient elements of the Program Research and Development Announcement (PRDA). This letter is not an integral part of the PRDA which is a self-contained document. In the event of any conflict between the contents of this executive summary letter and that of the PRDA, the PRDA language will prevail.

The Federal Energy Technology Center (FETC) has identified the need to support the development of novel, low cost concepts to recover, sequester or provide for the direct utilization of greenhouse gases. The greenhouse gases of interest are carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O), and are usually associated with the production and use of fossil fuels. Low cost concepts are sought that are broadly applicable to the utilization of fossil fuels (i.e., coal, natural gas, and oil) that would reduce emissions below those resulting from improvements or advances in system cycle efficiencies, that provide for reuse or production of valuable byproducts, and that provide innovative long-term storage or disposal of greenhouse gases. Potential offerors may address any combination or portion of the greenhouse gases of interest described in the attached PRDA. While the Government desires a coordinated and interrelated approach, each proposed greenhouse gas concept must be fully addressed separately (both technical and cost proposals) to facilitate the evaluation process. Should an offeror choose to integrate more than one greenhouse gas concept, a separate discussion of the advantages to this approach must be provided.

In an effort to stimulate the greatest possible interest and allow the widest latitude of response, the Government will utilize the enclosed solicitation method. While the Government encourages latitude, it is also our desire to develop a integrated program that emphasizes complementary technology throughout the breadth of greenhouse gases of interest.

Teaming arrangements among offerors are encouraged to ensure that the broad range of technical and economic issues are addressed. Participation of an industrial party with credible capability to demonstrate successful technologies at large scale is encouraged in early phases of the project. However, during Phase III, an industrial party located in the United States must perform a minimum of 30 percent of the work within the United States. Potential offerors are encouraged to seek additional sources of funding for any or all phases. Individuals, corporations, nonprofit organizations, small and small disadvantaged businesses, educational institutions, and state or local governments or other entities who wish to have a proposal evaluated should respond to the requirements of this PRDA. The offeror must propose a Statement of Work (SOW) that will meet the Government's objectives. A sample SOW format is presented in the attached PRDA. Specific details

and objectives for the research and development program are set forth in the PRDA objectives (See Section J, Attachment A).

The Government anticipates multiple awards for Phase I with a competitive down selection process occurring at the completion of Phase I and II. The initial phase will be largely exploratory involving technical and preliminary economic assessments of proposed concepts. The most promising methods emerging from this phase will be eligible for a second phase involving laboratory and bench scale development. The third and final phase will involve pilot and larger scale testing to prove the engineering feasibility of the technology. The duration of Phase I is expected to be 8 months, while the duration of Phase II shall not exceed 22 months. The duration of Phase III is anticipated to be 30 months. Multiple cost reimbursement type contracts will result from the PRDA, but the Government reserves the right to award the contract type deemed in its best interest.

It is anticipated that individual awards for Phase I will be approximately $50,000. The Government funding for the second and third phases could total up to approximately $1.5 million for each selected project. This, however, does not preclude consideration of longer or shorter projects at higher or lower estimated costs.

It is the Department's desire to encourage the widest participation including the involvement of small business concerns, and small disadvantaged business concerns. As a consequence, Phase I of this procurement is a partial set-aside. Subsequent down selections at the end of Phases I and II will not include partial set-aside preferences.

The Government does not anticipate providing any facilities or property for accomplishing this effort. Offerors are encouraged to propose utilization of existing facilities and make allowances for providing all necessary personnel, facilities, special test equipment, and materials to complete proposed project(s).

Proposals must be submitted in accordance with the requirements of the PRDA. Each of the required proposal parts should be bound separately and clearly labeled. The proposals must be received by the Contract Specialist not later than 3:00 p.m. local prevailing time on **November 18, 1997**, at the address below:

U.S. Department of Energy
Federal Energy Technology Center
ATTN: Raymond R. Jarr
3610 Collins Ferry Road
Morgantown, WV 26507-0880

Proposals must authorize a period for acceptance by the Government of not less than one hundred eighty (180) calendar days from the date specified for receipt of proposals. Furthermore, you are cautioned that late proposals, modifications, and withdrawals will be treated in accordance with Article L.053 of the PRDA.

Federal agencies and agents (i.e., Management and Operating (M&O) contractors and/or National Laboratories) are prohibited from submitting proposals, as a prime contractor, under this solicitation. Proposals which include performance, as a subcontractor, by DOE M&O contractors and/or National Laboratories are appropriate if the proposed use of any such entities is specifically authorized by the executive Federal agency managing the M&O or National Laboratory, and the work is not otherwise available from the private sector.

All requests for explanation or interpretation of any part of the PRDA shall be submitted in writing to the Contract Specialist at the aforementioned address. To allow a reply to reach all prospective offerors before the submission of their offers, your written questions must be received by the Contract Specialist by close of business on October 15, 1997. If the Government elects to answer the questions, the questions will be answered via an amendment to the solicitation with copies of both the questions and the answers being supplied to all prospective offerors, without reference to the originating sources. All amendments will be posted on the FETC's Homepage at {http://www.fetc.doe.gov/business/solicita.html}. For prospective offeror's who obtained a copy of the solicitation via FETC's Homepage should check this location frequently for any amendments. The Government reserves the right not to respond to questions received after October 15, 1997, nor respond to questions submitted by telephone, internet, or in person at any time.

Please complete and return the enclosed Intention to Propose form at the earliest practicable date. It is recommended that the offeror print this form out prior to completion as this form, along with the other forms/documents to be completed if a company chooses to propose, is not set up to accept input. The Intention to Propose form is contained not only in this file, but in a separate Word Perfect (W.P.) 6.1 file on this diskette entitled "intent.pro;" this should aid in printing the document. All files are formatted for printing on a post-script type printer with a base font of 10-point courier. To effectively print the attached document without overloading the printer, it is recommended that the offeror print only half the document out at one time. This will avoid printer control problems.

All communications concerning this PRDA should cite the PRDA number and be directed in writing to the attention of the Contract Specialist at the letterhead address.

Sincerely,

Original Signed.

Raymond R. Jarr
Contract Specialist
Acquisition and Assistance Division

Enclosure

SOLICITATION, OFFER AND AWARD	1. THIS CONTRACT IS A RATED ORDER UNDER DPAS (15 CFR 350) ▶	RATING	PAGE OF 1 92

2. CONTRACT NO.	3. SOLICITATION NO.	4. TYPE OF SOLICITATION	5. DATE ISSUED	6. REQUISITION/PURCHASE NO.
	DE-RA26-98FT35008	☐ SEALED BID (IFB) ☒ NEGOTIATED (PRDA)	September 15, 1997	26-98FT35008.000

7. ISSUED BY	CODE	8. ADDRESS OFFER TO *(If other than Item 7)*
U.S. Department of Energy Federal Energy Technology Center P.O. Box 880 Morgantown, WV 26507-0880		

NOTE: In sealed bid solicitations, "offer" and "offeror" mean "bid" and "bidder."

SOLICITATION

9. Sealed offers in original and _____ copies for furnishing the supplies or services in the Schedule will be received at the place specified in Item 8, or if handcarried, in the depository located in _____ until _____ local time _____.
(Hour) (Date)

CAUTION — LATE Submissions, Modifications, and Withdrawals: See Section L, Provision No. 52.214-7 or 52.215-10. All offers are subject to all terms and conditions contained in this solicitation.

10. FOR INFORMATION CALL: ▶	A. NAME	B. TELEPHONE NO. *(Include area code) (NO COLLECT CALLS)*
	Raymond R. Jarr, Contract Specialist	(304) 285-4088

11. TABLE OF CONTENTS

(✓)	SEC.	DESCRIPTION	PAGE(S)	(✓)	SEC.	DESCRIPTION	PAGE(S)
		PART I — THE SCHEDULE				PART II — CONTRACT CLAUSES	
X	A	SOLICITATION/CONTRACT FORM	1	X	I	CONTRACT CLAUSES	25
X	B	SUPPLIES OR SERVICES AND PRICES/COSTS	2			PART III — LIST OF DOCUMENTS, EXHIBITS AND OTHER ATTACH.	
X	C	DESCRIPTION/SPECS./WORK STATEMENT	4	X	J	LIST OF ATTACHMENTS	28
X	D	PACKAGING AND MARKING	5			PART IV — REPRESENTATIONS AND INSTRUCTION	
X	E	INSPECTION AND ACCEPTANCE	6	X	K	REPRESENTATIONS, CERTIFICATIONS AND OTHER STATEMENTS OF OFFERORS	54
X	F	DELIVERIES OR PERFORMANCE	7				
X	G	CONTRACT ADMINISTRATION DATA	8	X	L	INSTRS., CONDS., AND NOTICES TO OFFERORS	66
X	H	SPECIAL CONTRACT REQUIREMENTS	11	X	M	EVALUATION FACTORS FOR AWARD	90

OFFER *(Must be fully completed by offeror)*

NOTE: Item 12 does not apply if the solicitation includes the provisions at 52.214-16, Minimum Bid Acceptance Period.

12. In compliance with the above, the undersigned agrees, if this offer is accepted within 180 calendar days *(60 calendar days unless a different period is inserted by the offeror)* from the date for receipt of offers specified above, to furnish any or all items upon which prices are offered at the price set opposite each item, delivered at the designated point(s), within the time specified in the schedule.

13. DISCOUNT FOR PROMPT PAYMENT *(See Section I, Clause No. 52.232-8)* ▶	10 CALENDAR DAYS %	20 CALENDAR DAYS %	30 CALENDAR DAYS %	CALENDAR DAYS %

14. ACKNOWLEDGMENT OF AMENDMENTS *(The offeror acknowledges receipt of amendments to the SOLICITATION for offerors and related documents numbered and dated:*	AMENDMENT NO.	DATE	AMENDMENT NO.	DATE

15A. NAME AND ADDRESS OF OFFEROR	CODE	FACILITY	16. NAME AND TITLE OF PERSON AUTHORIZED TO SIGN OFFER *(Type or print)*

15B. TELEPHONE NO. *(Include area code)*	15C. CHECK IF REMITTANCE ADDRESS ☐ IS DIFFERENT FROM ABOVE — ENTER SUCH ADDRESS IN SCHEDULE	17. SIGNATURE	18. OFFER DATE

AWARD *(To be completed by Government)*

19. ACCEPTED AS TO ITEMS NUMBERED	20. AMOUNT	21. ACCOUNTING AND APPROPRIATION

22. AUTHORITY FOR USING OTHER THAN FULL AND OPEN COMPETITION: ☐ 10 U.S.C. 2304(c) ( ) ☐ 41 U.S.C. 253(c) ( )	23. SUBMIT INVOICES TO ADDRESS SHOWN IN *(4 copies unless otherwise specified)* ▶	ITEM

24. ADMINISTERED BY *(If other than Item 7)*	CODE	25 PAYMENT WILL BE MADE BY	CODE

26. NAME OF CONTRACTING OFFICER *(Type or print)*	27. UNITED STATES OF AMERICA *(Signature of Contracting Officer)*	28. AWARD DATE

IMPORTANT — Award will be made on this Form, or on Standard Form 26, or by other authorized official written notice.

PART I -- SECTION B

SUPPLIES OR SERVICES AND PRICES/COSTS

B.003 ITEMS BEING ACQUIRED (NOV 1991)

The contractor shall furnish all personnel, facilities, equipment, material, supplies, and services (except as may be expressly set forth in this contract as furnished by the Government) and otherwise do all things necessary for, or incident to, the performance of the following items of work:

Item 1 -- Research entitled "**Global Climate Change - Novel Concepts For Management of Greenhouse Gases**," in accordance with the Statement of Work, Part III, Section J, Attachment A to this contract.

Item 2 -- Reports in accordance with the reporting requirements described in Part III, Section J, Attachment B and the requirements set forth in Clause H.025a entitled "Preparation and Submission of Reports and Other Documents for DOE Review."

B.004 ESTIMATED COST AND FIXED FEE (APR 1984)

BASE CONTRACT/(PHASE I)

Estimated Cost . . . . . **(TBD)**

Fixed Fee . . . . . **(TBD)**

Total Estimated Cost and Fixed Fee . . . . . **(TBD)**

The contractor shall not proceed to the subsequent phase(s) identified below unless the Government issues a contract modification in accordance with Articles B.020(S) and H.038(S).

Phase II

Estimated Cost . . . . . **(TBD)**

Fixed Fee . . . . . **(TBD)**

Total Estimated Cost and Fixed Fee . . . . . **(TBD)**

Phase III

Estimated Cost . . . . . **(TBD)**

Fixed Fee . . . . . **(TBD)**

Total Estimated Cost and Fixed Fee . . . . . **(TBD)**

B.008a LIMITATION OF FUNDS (NOV 1991)

Pursuant to the clause entitled "Limitation of Funds," total funds in the amount of $**(To Be Determined)** are obligated herewith and made available for payment of allowable costs and fixed fee to be incurred from the effective date of this contract through the period estimated to end **(To Be Determined)**.

B.020(S) MULTIPLE AWARDS – PHASED ACQUISITIONS

The Government may elect to require the contractor to perform the phases identified in the Statement of Work, Section J, Attachment A. In the event a determination is made to continue into a subsequent phase(s), the Contracting Officer will issue a bilateral contract modification. The estimated cost and fixed fee of the contract will be increased by the amounts established in this Section B for each phase. The period of performance shall be extended in accordance with Article F.004b.

PART I -- SECTION C

DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

C.001 STATEMENT OF WORK (NOV 1991)

The Statement of Work is located in Part III -- Section J, Attachment A to this contract.

C.002 REPORTS (NOV 1991)

Reports shall be prepared and submitted in accordance with the reporting requirements described in Part III -- Section J, Attachment B, and the requirements set forth in Clause H.025a entitled "Preparation and Submission of Reports and Other Documents for DOE Review."

PART I -- SECTION D

PACKAGING AND MARKING

D.001 PACKAGING (AUG 1993)

A. Preservation, packaging, and packing for shipment or mailing of all items of work delivered hereunder shall be in accordance with good commercial practice and adequate to insure acceptance by common carrier and safe transportation at the most economical rate(s).

B. Except for those reports required by the Reporting Requirements Checklist of the contract, which are coded by A (As required) or X (With proposal) where the urgency of receipt of the report by the Government necessitates the use of the most expeditious method of delivery, reports deliverable under this contract shall be mailed by other than first-class mail, unless the urgency of the deliverable sufficiently justifies the use of first-class mail. The contractor shall not utilize certified or registered mail or private parcel delivery service for the distribution of reports under this contract without the advance approval of the Contracting Officer except for those reports coded A or X. The Hot Line Reports, described in Part III -- Section J, Attachment B, will be transmitted as described therein.

D.002 MARKING (AUG 1993)

A. Each package, report, or other deliverable shall be accompanied by a letter. The transmittal letter must indicate whether the contractor considers the delivered item to be a partial or full satisfaction of the requirement.

B. For any package, report, or other deliverable being delivered to a party other than the Contracting Officer, a copy of the document required in A. above shall be simultaneously provided to the office administering the contract, as identified in either Block 6 of the Face Page (SF 26) or in Section G of the contract, or if none, to the Contracting Officer.

PART I -- SECTION E

INSPECTION AND ACCEPTANCE

E.001 INSPECTION (NOV 1991)

Inspection of all items under this contract shall be accomplished by the DOE Contracting Officer's Representative (COR), or designee.

E.002 ACCEPTANCE (NOV 1991)

Final acceptance of all work and effort under this contract (including "Reporting Requirements," if any) shall be accomplished by the Contracting Officer.

PART I -- SECTION F

DELIVERIES OR PERFORMANCE

F.004b PERIOD OF PERFORMANCE (NOV 1991)

Phase I -- **(To Be Determined)**

The Government may elect to require the contractor to perform the phases identified in the Statement of Work, Part III -- Section J, Attachment A. In the event a determination is made to continue in a subsequent phase(s), the period of performance will be increased by the duration established below for each phase.

Phase II -- **(To Be Determined)**

Phase III -- **(To Be Determined)**

F.005 PRINCIPAL PLACE OF PERFORMANCE (NOV 1991)

(To Be Determined)

F.008 DELIVERY POINT (NOV 1991)

Delivery of all items deliverable under this contract, other than reports, shall be made F.O.B. DESTINATION to the following address:

U.S. Department of Energy
Federal Energy Technology Center
3610 Collins Ferry Road
Morgantown, WV 26505

PART I -- SECTION G

CONTRACT ADMINISTRATION DATA

G.001 CORRESPONDENCE PROCEDURES (JUN 1997)

All correspondence submitted by the contractor (except for invoices and reports) shall be subject to the following procedures:

A. Technical Correspondence

Technical correspondence concerning performance of this contract shall be addressed to the DOE Contracting Officer's Representative (COR), with an information copy of the correspondence to the DOE Contracting Officer (CO) and to the cognizant Government Contract Administration Office (if other than DOE) designated on the face page of this contract.

B. Patents/Technical Data Correspondence

Correspondence concerning patent or technical data issues shall be addressed to the following:

Intellectual Property Law Division
U.S. Department of Energy
Chicago Operations Office
9800 South Cass Avenue
Building 201
Argonne, IL 60439

Submit an information copy to the FETC CO, the COR, and the Patent Attorney at the following address:

U.S. Department of Energy
Federal Energy Technology Center
ATTN: Patent Attorney, MS-A03
P.O. Box 880
Morgantown, WV 26507-0880

C. Non-Technical Administrative Correspondence

1. If a Government Contract Administration Office is designated in Block 6 on the face page of this contract, all non-technical administrative correspondence shall be addressed to the CO at the Government Contract Administration Office so designated, with information copies of the correspondence to the DOE CO and the COR.

2. If no Government Contract Administration Office is designated in Block 6 on the face page of this contract, all non-technical administrative correspondence shall be addressed to the DOE CO with an information copy of the correspondence to the COR.

D. Subject Line(s)

All correspondence shall contain a subject line as illustrated below:

"SUBJECT: Contract No. DE-RA26-98FT35008"

G.002 DESIGNATION OF PATENT COUNSEL (DEC 1996)

The Federal Energy Technology Center, U.S. DOE, ATTN: METC Patent Attorney, M/S A03, P.O. Box 880, Morgantown, West Virginia, 26507-0880, is hereby designated to represent the Contracting Officer in administering the Patents and Technical Data clauses of this contract. Correspondence with respect to these clauses, as well as any general questions concerning these issues, should be directed to the FETC Patent Attorney with information copies to the CO and the COR.

G.003a SUBMISSION OF VOUCHERS/INVOICES (COST-PLUS-FIXED-FEE CONTRACTS) (DEC 1996)

A. Introduction

These instructions are provided for use by contractors in the preparation and submission of vouchers requesting reimbursement for work performed under cost-plus-fixed-fee type contracts. Compliance with these instructions will reduce correspondence and other causes for delay to a minimum and will thus promote prompt payments to the contractor.

B. Voucher Form

In requesting reimbursement, contractors shall use Standard Form 1034 (Public Voucher for Purchases and Services Other Than Personal), supported by a Statement of Cost. An acceptable substitute (which provides the same necessary information) may be used provided the written consent of the Contracting Officer is first obtained.

C. Preparation

Standard Form 1034 shall be completed in accordance with the following instructional notations:

1. Leave blank.

2. Enter voucher number (number consecutively, commencing with "1").

3. Enter date voucher prepared.

4. Enter contract number and date of contract award.

5. Enter contractor's name, mailing address, and telephone number of office responsible for submitting voucher.

6. If a task order or project agreement is involved in the billing, enter the number and date thereof; otherwise, leave blank.

7. Identify the period the billing covers (e.g., "January 1990" or "January-March 1990").

8. Enter the dollar amount of this billing. The amount claimed for costs must agree with the amount reflected in the attached Statement of Cost. The amount claimed for fixed fee should be based on percentage of completion of the work.

9. Place an "X" in the appropriate block for the type of payment for which reimbursement is requested.

The Statement of Cost shall be completed, making due allowance for the contractor's cost accounting system. Costs claimed shall be only those recorded costs authorized for billing by the payment provisions of the contract. Indirect costs shall be claimed at no more than those rates which have been approved for billing purposes by the Contracting Officer. Additional supporting data for claimed costs shall be provided in such form and reasonable detail as an authorized representative of the Contracting Officer may require.

D. Submission

The Certification of the Statement of Cost attached to the original voucher must be signed by a responsible official of the contractor. Submit the original voucher (supported by a copy of the Statement of Cost) to the following address:

U.S. Department of Energy
Oak Ridge Financial Service Center
P.O. Box 4787
Oak Ridge, TN 37831

In addition, submit two copies of the signed voucher (each supported by a copy of the Statement of Cost) to the following address:

U.S. Department of Energy
Federal Energy Technology Center
ATTN: Accounts Payable, M/S A02
P.O. Box 880
Morgantown, WV 26507-0880

E. Billing Period

Vouchers shall be submitted no more frequently than monthly (unless prior written consent of the Contracting Officer for more frequent billing is obtained). The period of performance covered by vouchers should be consistent with the requirements of the contract.

SPECIAL CONTRACT REQUIREMENTS

H.001 CONTINUOUS NUMBERING (NOV 1991)

Due to automated procedures employed in formulating this document, clauses contained within it may not always be continuously numbered.

H.002 TECHNICAL DIRECTION (NOV 1991)

A. Performance of the work under this contract shall be subject to the technical direction of the DOE Contracting Officer's Representative (COR). The term "technical direction" is defined to include, without limitation:

1. Directions to the contractor which redirect the contract effort, shift work emphasis between work areas or tasks, require pursuit of certain lines of inquiry, fill in details or otherwise serve to accomplish the contractual Statement of Work.

2. Provision of written information to the contractor which assists in the interpretation of drawings, specifications or technical portions of the work description.

3. Review and, where required by the contract, approval of technical reports, drawings, specifications, and technical information to be delivered by the contractor to the Government under the contract.

B. Technical direction must be within the scope of work stated in the contract. The COR does not have the authority to, and may not, issue any technical direction which:

1. Constitutes an assignment of additional work outside the Statement of Work;

2. Constitutes a change as defined in the contract clause entitled "Changes";

3. In any manner causes an increase or decrease in the total estimated contract cost, the fixed fee (if any), or the time required for contract performance;

4. Changes any of the expressed terms, conditions, or specifications of the contract; or

5. Interferes with the contractor's right to perform the terms and conditions of the contract.

C. All technical directions shall be issued in writing by the COR.

D. The contractor shall proceed promptly with the performance of technical directions duly issued by the COR in the manner prescribed by this clause and within his authority under the provisions of this clause. If, in the opinion of the contractor, any instruction or direction by the COR falls within one of the categories defined in B.1. through 5. above, the contractor shall not proceed but shall notify the Contracting Officer in writing within five (5) working days after receipt of any such instruction or direction and shall request the Contracting Officer to modify the contract accordingly. Upon receiving the notification from the contractor, the Contracting Officer shall either:

1. Advise the contractor in writing within thirty (30) days after receipt of the contractor's letter that the technical direction is within the scope of the contract effort and does not constitute a change under the "Changes" clause of the contract; or

2. Advise the contractor in writing within a reasonable time that the Government will or will not issue a written change order.

E. A failure of the contractor and Contracting Officer to agree that the technical direction is within the scope of the contract, or a failure to agree upon the contract action to be taken with respect thereto shall be subject to the provisions of the clause entitled "Disputes -- Alternate I."

H.003 MODIFICATION AUTHORITY (NOV 1991)

Notwithstanding any of the other clauses of this contract, the Contracting Officer shall be the only individual authorized to:

A. Accept nonconforming work,

B. Waive any requirement of this contract, or

C. Modify any term or condition of this contract.

H.004c GOVERNMENT PROPERTY AND DATA (NOV 1991)

A. Contractor-Acquired Property -- Acquisition Authorization Requirements

1. In the course of performance of this contract, the contractor may only acquire and direct charge to this contract such facilities, equipment (including office equipment), furniture, fixtures, or other real or personal property items as have been specifically authorized by the Contracting Officer by inclusion of such items on the LIST OF GOVERNMENT PROPERTY -- CONTRACTOR ACQUIRED, Part III -- Section J, Attachment C, to this contract.

2. Except as may otherwise be provided under this contract, the contractor is not authorized to acquire as a direct charge item under the contract any facility, equipment (including office equipment), furniture, fixtures, or

other real or personal property items having a unit acquisition cost of $10,000 or less. Exceptions to this rule will rarely be granted, but requests from the contractor for such exceptions will be considered on a case-by-case basis. As in the case of other property acquisition requests, justification in support of the purchase of such items shall be provided as set forth in Paragraph 3. below.

3. The contractor may request authorization for acquisition of additional direct charge items from the Contracting Officer. Any such request shall include the following, where applicable:

   a. Sufficient detail to justify and support the acquisition, including an itemized description and cost estimate;

   b. An analysis of the most economical method of acquisition (e.g., lease versus purchase); and

   c. A description of the material equity arising from any proposed lease arrangement, such as option credits.

4. Any changes in the acquisition authorization shall be reflected in a modification to this contract which amends the LIST OF GOVERNMENT PROPERTY -- CONTRACTOR ACQUIRED.

5. Authorization to acquire does not constitute consent to the placement of a subcontract.

B. Government-Furnished Property and Data

The Government is not obligated to furnish any real or personal property or data under this contract.

C. Reporting Requirements

1. The reports required in accordance with 48 CFR 945 shall be submitted on the forms provided by DOE in accordance with 48 CFR 945 and the forms' instructions.

2. The reports are to include all capital equipment and sensitive items acquired or furnished under this contract, whether or not listed on the attachments referenced above.

H.005 KEY PERSONNEL (NOV 1991)

Notwithstanding the reference in the contract clause entitled "Key Personnel" to an attachment to this contract, the contractor's key personnel are as follows:

NAME	TITLE
(To Be Determined)	**(To Be Determined)**

The clause entitled "Key Personnel" contains a requirement for notification to the Contracting Officer reasonably in advance of diverting of, or substitution for, any of these individuals. That period of time shall not be less than thirty (30) days.

H.006 SUBCONTRACTS (NOV 1991)

Prior to the placement of subcontracts and in accordance with the clause, "Subcontracts (Cost-Reimbursement and Letter Contracts)," the contractor shall insure that:

A. They contain all of the clauses of this contract (altered when necessary for proper identification of the contracting parties) which contain a requirement for such inclusion in applicable subcontracts;

B. Any applicable subcontractor Certificate of Current Cost or Pricing Data (see FAR 15.804-2) and subcontractor Representations and Certifications; and

C. Any required prior notice and description of the subcontract is given to the Contracting Officer and any required consent is received. Except as may be expressly set forth therein, any consent by the Contracting Officer to the placement of subcontracts shall not be construed to constitute approval of the subcontractor or any subcontract terms or conditions, determination of the allowability of any cost, revision of this contract or any of the respective obligations of the parties thereunder, or creation of any subcontractor privity of contract with the Government.

H.007a SERVICES OF CONSULTANTS (NOV 1991)

A. In addition to the provisions of the clause of this contract entitled "Subcontracts (Cost-Reimbursement and Letter Contracts)," the contractor shall obtain the Contracting Officer's written consent prior to reimbursing any of its employees as a "consultant" under this contract, or prior to awarding any subcontract for consulting services which will exceed ten (10) days in any calendar year or exceed a total value of $2,500. The contractor shall obtain and furnish to the Contracting Officer information concerning the need for and selection of any subcontracts for consultant services and the reasonableness of the fees to be paid, including, but not limited to, whether fees to be paid to any consultant exceed the lowest fee charged by such consultant to others for performing consulting services of a similar nature.

H.010 CONFIDENTIALITY OF INFORMATION (NOV 1991)

A. To the extent that the work under this contract requires that the contractor be given access to confidential or proprietary business, technical, or financial information belonging to the Government or other companies, the contractor shall after receipt thereof, treat such information as confidential and

agrees not to appropriate such information for its own use or to disclose such information to third parties unless specifically authorized by the Contracting Officer in writing. The foregoing obligations, however, shall not apply to:

1. Information which, at the time of receipt by the contractor, is in public domain;

2. Information which is published after receipt thereof by the contractor or otherwise becomes part of the public domain through no fault of the contractor;

3. Information which the contractor can demonstrate was in its possession at the time of receipt thereof and was not acquired directly or indirectly from the Government or other companies;

4. Information which the contractor can demonstrate was received by it from a third party who did not require the contractor to hold it in confidence.

B. The contractor shall obtain the written agreement, in a form satisfactory to the Contracting Officer, of each employee permitted access, whereby the employee agrees that he will not discuss, divulge or disclose any such information or data to any person or entity except those persons within the contractor's organization directly concerned with the performance of the contract.

C. The contractor agrees, if requested by the Government, to sign an agreement identical, in all material respects, to the provisions of this clause, with each company supplying information to the contractor under this contract, and to supply a copy of such agreement to the Contracting Officer. From time to time upon request of the Contracting Officer, the contractor shall supply the Government with reports itemizing information received as confidential or proprietary and setting forth the company or companies from which the contractor received such information.

D. The contractor agrees that upon request by DOE it will execute a DOE-approved agreement with any party whose facilities or proprietary data it is given access to or is furnished, restricting use and disclosure of the data or the information obtained from the facilities. Upon request by DOE, such an agreement shall also be signed by contractor personnel.

E. This clause shall flow down to all subcontracts.

H.012b INDIRECT COSTS (NOV 1991)

A. Pending establishment of final indirect cost rates for any period, billing, and reimbursement of indirect costs shall be made on the basis of provisional rates approved by the Contracting Officer. The following rates are the Contracting Officer approved rates as of the date of this contract:

Indirect Costs	Base of Application	Provisional Rate(s) Contractor's Fiscal Year[1]		
		FY	FY	FY
(TBD)	**(TBD)**	**(TBD)**	**(TBD)**	**(TBD)**

[1] For Contractor's FY beginning **(TBD)** and ending **(TBD)**.

B. If, during the period of performance the contractor's provisional rates change, the contractor shall notify the Contracting Officer in writing. The contractor shall also submit this notification to the cognizant Government audit agency and the cognizant Government agency for administration if this contract has been delegated. After notification from the cognizant administration agency and/or audit agency, the Contracting Officer shall modify the contract incorporating the DOE-approved provisional rates for the current period.

C. If, during the period of performance of this contract, provisional rates have not been established for a particular fiscal year via a contract modification, then the contractor shall continue to bill those rates most recently approved by the Contracting Officer, until such time as the contract is modified to reflect the most current approved rates.

H.012d INDIRECT COSTS (NOV 1991) (This clause is only applicable if there are established indirect rate agreements.)

Pending establishment of final indirect cost rates for any period, billing and reimbursement of indirect costs shall be made on the basis of provisional rates approved by the cognizant Contracting Officer or Government auditor. When a rate change occurs, the contractor shall inform the Contracting Officer by letter of the indirect rate change. This notification shall include a copy of the cognizant Contracting Officer or auditor's approval and the cost impact of the rate change on the program.

H.013 GUARANTEED FINAL REPORT (NOV 1991)

Notwithstanding the applicable cost principles of the Federal Acquisition Regulation (FAR) and the DOE Acquisition Regulation (DEAR) in effect on the date of this contract, and as authorized by Paragraph (a) of the clause of this contract entitled "Allowable Cost and Payment," the contractor agrees to manage this contract in such a manner so as to guarantee to the Government the delivery of an acceptable Final Report. It is the contractor's responsibility to ensure at all times that adequate funds remain to cover all allowable costs necessary for the preparation and delivery of the acceptable Final Report. All costs incurred by the contractor during preparation and delivery of the acceptable Final Report that are in excess of the funds remaining in the contract shall be borne by the contractor.

H.018 PAYMENT OF OVERTIME PREMIUMS (NOV 1991)

A. Pursuant to Paragraph A. of the clause entitled "Payment for Overtime Premiums," the total cost of this contract contains overtime premium costs as listed below:

Overtime Premium: None

B. Any premium cost required in excess of the above amount shall require the prior written approval of the Contracting Officer.

H.021 FAR 52.232-18 -- AVAILABILITY OF FUNDS (APR 1984)

Funds are not presently available for this contract. The Government's obligation under this contract is contingent upon the availability of appropriated funds from which payment for contract purposes can be made. No legal liability on the part of the Government for any payment may arise until funds are made available to the Contracting Officer for this contract and until the contractor receives notice of such availability, to be confirmed in writing by the Contracting Officer.

H.024 RIGHTS TO PROPOSAL DATA (NOV 1991)

Pursuant to the clause entitled "Rights to Proposal Data" the following is inserted therein:

"... pages **(To Be Determined)**"

"... proposal dated **(To Be Determined)**"

H.025a PREPARATION AND SUBMISSION OF REPORTS AND OTHER DOCUMENTS FOR DOE REVIEW (AUG 1997)

A. Uniform Contractor Reporting

The contractor shall prepare and submit (postage prepaid) the reports indicated on the "Reporting Requirements Checklist" attached to this contract (Part III, Section J, Attachment B) to the DOE Reports Receipt Coordinator. Detailed guidance for preparation of the specified reports is also contained in Part III, Section J, Attachment B. The level of detail the contractor must provide in the reports shall be commensurate with the scope and complexity of the work and the instructions included with the Checklist. The contractor shall be responsible for levying appropriate reporting requirements on any subcontractors in such a manner as to ensure that data submitted is responsive to DOE requirements. If subcontractors are involved, the prime contractor report submissions shall be structured to permit clear identification of the subcontractor's cost and manpower inputs.

B. Other Contract Reporting Requirements

Government property reports, if applicable, shall be prepared and submitted in accordance with the "Government Property" clause of this contract and as described in Part III, Section J, Attachment B. If this contract contains a Small/ Disadvantaged Business Subcontracting Plan, subcontracting reports shall be prepared and submitted in accordance with the Plan and the contract clause entitled "Small Business and Small Disadvantaged Business Subcontracting Plan."

C. DOE Review and Approval of Scientific and Technical Documents

The contractor shall submit to DOE for review and approval all documents generated by the contractor, or any subcontractor, which communicate the results of scientific or technical work supported by DOE under this contract, whether or not specifically identified in the contract, prior to submission for publication, announcement, or presentation. Such documents include, in addition to technical reports identified on the Reporting Requirements Checklist, other scientific and technical reports, journal articles, conference papers and proceedings, etc.

All these documents require clearance by the Intellectual Property Law Division prior to publication, announcement, or presentation. The DOE Reports Receipt Coordinator is responsible for obtaining patent clearance for all applicable technical reports identified on the Reporting Requirements Checklist. However, journal articles, conference papers and proceedings, etc., usually must be cleared by the Intellectual Property Law Division in a relatively short period of time. Therefore, the contractor shall make the following direct distribution of these documents upon authorization by the COR:

Furnish one copy of each document concurrently to the COR and to the Intellectual Property Law Division at the following addresses:

U.S. Department of Energy
Federal Energy Technology Center
ATTN: Contracting Officer's Representative (By Name)
P.O. Box 880, 3610 Collins Ferry Road
Morgantown, WV 26507-0880

U.S. Department of Energy
Intellectual Property Law Division
Chicago Operations Office
9800 South Cass Avenue
Building 201
Argonne, IL 60439

All documents submitted for patent clearance shall be accompanied by a properly completed FETC F 1332.1 “Request for Patent Clearance for Release of Contracted Research Documents.”

All final copies of documents designated by the COR for publication shall be prepared in accordance with the article in Section J entitled "Guidelines for Preparation of Electronic Versions of Reports."

D. Contractor Press Releases

The DOE policy and procedure on news releases requires that all contractor press releases be reviewed and approved by DOE prior to issuance. Therefore, the contractor shall, at least ten (10) days prior to the planned issue date, submit a draft copy to the Contracting Officer of any planned press releases related to the work performed under this contract. The Contracting Officer will then obtain necessary reviews and clearances and provide the contractor with the results of such reviews prior to the planned issue date.

H.031 OFFEROR REPRESENTATIONS AND CERTIFICATIONS (JUN 1991)

The Representations, Certifications, and other Statements of Bidders/Offerors submitted by the contractor are incorporated into this contract by reference.

H.034 SAFETY AND HEALTH (NOV 1991)

A. The contractor shall have in place, within 60 days of contract initiation, a safety and health program for the DOE work being performed consistent and in accordance with applicable Federal, State, and local laws, including codes, ordinances, and regulations.

B. The contractor shall take all necessary precautions in the performance of the work under this contract to protect the safety and health of employees and the public and shall comply with all legally required safety and health regulations and requirements.

C. The Contracting Officer or his authorized representative shall have access to and the right to examine the contractor's safety and health program (e.g., written policies and procedures) related to this contract upon request.

D. The contractor agrees to include Paragraphs A, B, and C of this clause in first-tier subcontracts and agrees to enforce the terms of this clause including corrective action for noncompliance. In addition, the Contracting Officer or his authorized representative shall have access to and the right to examine the subcontractor's safety and health program (e.g., written policies and procedures) related to the subcontract upon request.

H.035 PERMITS AND LICENSES (NOV 1991)

A. The contractor shall obtain any and all ES&H approvals (e.g., permits and licenses) required by Federal, State, and local

laws (including codes, ordinances, and regulations) necessary to complete the DOE work.

Within 60 days of contract initiation, the contractor shall submit to the COR a list of ES&H approvals which, in the contractor's opinion, shall be required to complete the work under this contract. The list shall include the name of the approval being sought, the granting agency, and the submittal/approval schedule. The COR shall be notified as specific items are added or removed from the list and prosecuted through their approval cycles.

B. In obtaining any ES&H approvals, the contractor shall comply with all Federal, State, and local laws; including codes, ordinances, and regulations.

C. The contractor agrees to include Paragraphs A and B of this clause in first-tier subcontracts and agrees to enforce the terms of this clause including corrective action for noncompliance.

H.036 ENVIRONMENTAL PROTECTION (NOV 1991)

A. The contractor shall have in place, within 60 days of contract initiation, an environmental protection program to safeguard environmental resources with respect to the work being performed as required by applicable Federal, State, and local laws, including codes, ordinances, and regulations and as defined in Paragraph B below.

B. In addition to complying with the requirements set forth in the "Clean Air and Water" clause (FAR 52.223-2) in the performance of this contract, the contractor shall comply, as applicable, with the following:

1. The Clean Air Act, as amended;
2. The Clean Water Act, as amended;
3. The Safe Drinking Water Act, as amended;
4. The Resource Conservation and Recovery Act of 1976, as amended;
5. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended;
6. The Toxic Substances Control Act, as amended;
7. Noise Control Act, as amended;
8. Endangered Species Act;
9. National Historic Preservation Act;
10. The Marine Protection, Research, and Sanctuaries Act of 1972, as amended;
11. Fish and Wildlife Coordination Act;
12. The Coastal Zone Management Act of 1972, as amended;
13. The Coastal Barrier Resource Act of 1982;
14. The Federal Insecticide, Fungicide, and Rodenticide Act, as amended;
15. The Occupational Safety and Health Act, and
16. Other Federal and non-Federal environmental protection laws, codes, ordinances, and regulations, if identified in writing by the Contracting Officer.

Failure to list a law above, or to identify a requirement having the force and effect of law, shall not be construed as waiving a requirement for the contractor to comply with such law or requirement.

C. The Contracting Officer or his authorized representative shall have, access to and the right to examine the contractor's environmental protection program (e.g., written policies and procedures) related to this contract upon request.

D. The contractor agrees to include Paragraphs A, B, and C of this clause in first-tier subcontracts and agrees to enforce the terms of this clause including corrective action for noncompliance. In addition, the Contracting Officer or his authorized representative shall have access to and the right to examine the subcontractor's environmental protection program (e.g., written policies and procedures) related to the subcontract upon request.

H.037 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROGRAM (NOV 1991)

The contractor shall have in place, within 60 days of contract initiation, a Quality Assurance/Quality Control (QA/QC) program that ensures:

A. The level of accuracy, precision, and reproducibility of data is adequate to fulfill the objectives of the work to be performed under this contract.

B. The safety and health of employees and the public and compliance with policies and procedures that safeguard environmental resources.

The QA/QC program shall, as determined applicable by the contractor, include the following:

1. A procedure to control experimental conditions using technical standards, instructions, and other appropriate means commensurate with the complexity and risk of the work;

2. A procedure to identify, control, and maintain components, equipment, facilities, hardware, and material;

3. A procedure to control handling, storage, shipping, cleaning, and preservation to prevent damage, loss, or deterioration;

4. A procedure to control calibration, maintenance, accountability, and use of measuring and testing equipment used for monitoring and data collection;

5. A method(s) to ensure that designs use sound engineering/ scientific principles and current appropriate standards;

6. A procedure to ensure that purchased items and services meet requirements established for them by the performing organization;

7. A procedure to specify when and what type of inspections are required;

8. A procedure to demonstrate that equipment and processes perform as intended; and

9. Procedures to continually improve the quality of the work done for DOE through the improvement of work practices guided by internal performance assessment.

The Contracting Officer or his authorized representative shall have access to and the right to examine the contractor's QA/QC program (e.g., written policies and procedures) related to this contract upon request.

H.038(S) MULTIPLE AWARDS — PHASED ACQUISITIONS (APR 1989)

A determination by the Contracting Officer to continue into subsequent phases will be restricted to the current phase contractor(s). The determination to select contractor(s) for a succeeding phase(s) will be on a competitive down selection process occurring at the completion of Phases I and II, based on the contractor's progress in the current phase, evaluation of the technical approach for planned activities for the upcoming phase, and availability of funds.

The contractor shall submit a comprehensive report at least 60 days prior to completion of the current phase, which shall as a minimum describe the actual and projected accomplishments in the current phase, including schedule and costs, and provide a detailed technical proposal, including schedule and costs for the upcoming phase. In the event the Government makes a determination to continue into a subsequent phase(s), a bilateral contract modification will be issued in accordance with Article B.020(S).

The following technical evaluation criteria and program policy factors will be applied in the determination to continuation into a subsequent phase(s):

A. Technical Proposal Evaluation Criteria

1. SCIENTIFIC/TECHNICAL INNOVATION

The extent to which the proposed work moves beyond the current state-of-the-art, using path-breaking novel, “revolutionary” concepts. Novelty and uniqueness of the proposed concept or application of the proposed concept. The possibility of a science or engineering breakthrough. Readily distinguishable approach from past and current practice and investigations. Significant scientific and/or technically challenging concepts. The extent to which the application of the proposed concept would reduce emissions below those resulting from improvements

or advances in system cycle efficiencies; provides for reuse or production of valuable byproducts; or provides innovative long-term storage or disposal of greenhouse gases.

2. IMPACT

The potential impact in terms of applicability to a large number of sites and quantity (tons) of greenhouse gases that would be recovered or sequestered, and the feasibility of the proposed concept for the development of path-breaking, less costly means to addressing greenhouse gas emissions. If fundamental scientific knowledge and understanding is proposed, the extent to which the knowledge can serve as a basis for the development of path-breaking technologies to reduce greenhouse gas emissions. Potential cost reductions.

3. TECHNICAL APPROACH AND UNDERSTANDING

The manner in which the offeror proposes to accomplish the work as evidenced by the quality, conciseness, and completeness of the proposal, including identification of anticipated problems and proposed solutions. The soundness and level of adequacy of the proposed work to show progress toward proving the feasibility of the concept. The degree to which the objectives of the preceding phase were met at the time that the current application was made. Clarity of the discussion of the technical basis for the proposed work including discussions on relevant technical issues, existing technical barriers, and pertinent research past and current. Technology effectively related to the PRDA objectives.

4. QUALIFICATION OF ORGANIZATION AND KEY PERSONNEL

The qualifications and pertinent experience of the Principal Investigators (PI), other key staff, and consultants, if any. The qualifications of any proposed U.S. industrial partner in regard to the capability to demonstrate successful technologies at large scale. The rationale for and corporate commitment to any teaming arrangement. Availability and time commitments of proposed personnel.

5. FACILITIES

Type, quality, and availability of the proposed equipment, materials, and facilities. Adequacy of the proposed facilities to conduct and support laboratory/bench scale testing, prototype development, and field testing activities. Justification for purchase or lease of facilities, equipment, or materials.

The evaluation of proposals at the conclusion of Phase I will be conducted using preestablished weights to determine the relative merits of the contractor's proposal in accordance with the technical evaluation criteria.

Criterion 1 is worth 30 percent, Criterion 2 is worth 20 percent, Criterion 3 is worth 25 percent, Criterion 4 is worth 15 percent, and Criterion 5 is worth 10 percent.

The evaluation of proposals at the conclusion of Phase II will be conducted using preestablished weights to determine the relative merits of the contractor's proposal in accordance with the technical evaluation criteria.

Criteria 1 and 5 are each 15 percent, Criteria 2 and 4 are each worth 20 percent, and Criterion 3 is worth 30 percent.

B. Program Policy Factors.

Program policy factors are those factors that are not indicative of the proposer's individual merit, but are relevant and essential to the process of choosing which proposal(s) will best achieve the program goals. The following program policy factors shall be considered by the Selection Official in the competitive down selection process.

1. It may be desirable to select a project(s) for award that can make a substantial contribution to the development of technological options for greenhouse gas emissions reduction.

2. It may be desirable to select a project(s) for award which complement or enhance DOE's programmatic objectives.

3. It may be desirable to select a project(s) for award that represents a diversity of technology concepts and applications, as well as technical approaches.

4. It may be desirable to select a project(s) for award of less technical merit than another project(s), if such a selection will optimize use of available funds by allowing more projects to be supported while not being detrimental to the overall objectives of the program.

5. It may be desirable to select a project(s) for award of less technical merit than another project(s), if such a selection will improve the participation of small businesses.

DOE SET 304
COST-REIMBURSEMENT SERVICE CONTRACTS

I.002 CLAUSES INCORPORATED BY REFERENCE

This section of the solicitation incorporates the following provisions/clauses by reference, with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available.

I.003 FAR 52.202-1 -- DEFINITIONS (OCT 1995), DEAR 952.202-1 DEFINITIONS (APR 1994)
I.004 FAR 52.203-3 -- GRATUITIES (APR 1984)
I.005 FAR 52.203-5 -- COVENANT AGAINST CONTINGENT FEES (APR 1984)
I.006 FAR 52.203-6 -- RESTRICTIONS ON SUBCONTRACTOR SALES TO THE GOVERNMENT (OCT 1995)
I.007 FAR 52.203-7 -- ANTI-KICKBACK PROCEDURES (JUL 1995)
I.009 FAR 52.203-10 -- PRICE OR FEE ADJUSTMENT FOR ILLEGAL OR IMPROPER ACTIVITY (SEP 1990)
I.010 FAR 52.203-12 -- LIMITATION ON PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (JAN 1990)
I.011 FAR 52.204-4 -- PRINTING/COPYING DOUBLE-SIDED ON RECYCLED PAPER (JUN 1996)
I.012 DEAR 952.208-70 -- PRINTING (APR 1984)
I.013 FAR 52.209-6 -- PROTECTING THE GOVERNMENT'S INTEREST WHEN SUBCONTRACTING WITH CONTRACTORS DEBARRED, SUSPENDED, OR PROPOSED FOR DEBARMENT (JUL 1995)
I.014 DEAR 952.211-72 -- UNIFORM REPORTING SYSTEM (JUN 1996)
I.015 FAR 52.215-2 -- AUDIT AND RECORDS -- NEGOTIATION (AUG 1996) AND ALTERNATE II (JAN 1997)
I.016 FAR 52.215-22 -- PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA (OCT 1995)
I.017 FAR 52.215-23 -- PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA -- MODIFICATIONS (OCT 1995)
I.018 FAR 52.215-24 -- SUBCONTRACTOR COST OR PRICING DATA (OCT 1995)
I.019 FAR 52.215-25 -- SUBCONTRACTOR COST OR PRICING DATA -- MODIFICATIONS (OCT 1995)
I.020 FAR 52.215-26 -- INTEGRITY OF UNIT PRICES (JAN 1997) AND ALTERNATE I (JAN 1997)
I.021 FAR 52.215-27 -- TERMINATION OF DEFINED BENEFIT PENSION PLANS (MAR 1996)
I.022 FAR 52.215-30 -- FACILITIES CAPITAL COST OF MONEY (SEP 1987)
I.023 FAR 52.215-31 -- WAIVER OF FACILITIES CAPITAL COST OF MONEY (SEP 1987)
I.024 FAR 52.215-33 -- ORDER OF PRECEDENCE (JAN 1986)
I.025 FAR 52.215-40 -- NOTIFICATION OF OWNERSHIP CHANGES (FEB 1995)
I.026 FAR 52.215-42 -- REQUIREMENTS FOR COST OR PRICING DATA OR INFORMATION OTHER THAN COST OR PRICING DATA MODIFICATIONS (JAN 1997)
I.027 DEAR 952.216-7 -- ALLOWABLE COST AND PAYMENT (MAR 1997) AND ALTERNATES I AND II
I.028 FAR 52.216-8 -- FIXED FEE (MAR 1997)
I.031 FAR 52.219-8 -- UTILIZATION OF SMALL, SMALL DISADVANTAGED AND WOMEN-OWNED SMALL BUSINESS CONCERNS (OCT 1995)
I.032 FAR 52.219-9 -- SMALL, SMALL DISADVANTAGED AND WOMEN-OWNED SMALL BUSINESS SUBCONTRACTING PLAN (AUG 1996)
I.033 FAR 52.219-16 -- LIQUIDATED DAMAGES -- SUBCONTRACTING PLAN (OCT 1995)
I.034 FAR 52.222-1 -- NOTICE TO THE GOVERNMENT OF LABOR DISPUTES (FEB 1997)
I.035 FAR 52.222-2 -- PAYMENT FOR OVERTIME PREMIUMS (JUL 1990)
I.036 FAR 52.222-3 -- CONVICT LABOR (AUG 1996)
I.037 FAR 52.222-4 -- CONTRACT WORK HOURS AND SAFETY STANDARDS ACT -- OVERTIME COMPENSATION (JUL 1995)
I.038 FAR 52.222-26 -- EQUAL OPPORTUNITY (APR 1984)
I.039 FAR 52.222-28 -- EQUAL OPPORTUNITY PREAWARD CLEARANCE OF SUBCONTRACTS (APR 1984)
I.040 FAR 52.222-35 -- AFFIRMATIVE ACTION FOR SPECIAL DISABLED AND VIETNAM ERA VETERANS (APR 1984)
I.041 FAR 52.222-36 -- AFFIRMATIVE ACTION FOR HANDICAPPED WORKERS (APR 1984)
I.042 FAR 52.222-37 -- EMPLOYMENT REPORTS ON SPECIAL DISABLED VETERANS AND VETERANS OF THE VIETNAM ERA (JAN 1988)
I.045 FAR 52.223-2 -- CLEAN AIR AND WATER (APR 1984)
I.046 FAR 52.223-6 -- DRUG-FREE WORKPLACE (JAN 1997)
I.047 FAR 52.223W-14 -- TOXIC CHEMICAL RELEASE REPORTING (OCT 1996)
I.049 FAR 52.225-11 -- RESTRICTIONS ON CERTAIN FOREIGN PURCHASES (OCT 1996)
I.050 FAR 52.225-19 -- EUROPEAN UNION SANCTION FOR SERVICES (JAN 1996)
I.051 FAR 52.228-7 -- INSURANCE -- LIABILITY TO THIRD PERSONS (MAR 1996)
I.052 FAR 52.232-17 -- INTEREST (JUN 1996)
I.053 FAR 52.232-20 -- LIMITATION OF COST (APR 1984)
I.054 FAR 52.232-22 -- LIMITATION OF FUNDS (APR 1984)
I.055 FAR 52.232-23 -- ASSIGNMENT OF CLAIMS (JAN 1986)
I.056 FAR 52.232-25 -- PROMPT PAYMENT (JUN 1997)
I.057 FAR 52.232-33 -- MANDATORY INFORMATION FOR ELECTRONIC FUNDS TRANSFER PAYMENT (AUG 1996)
I.058 FAR 52.233-1 -- DISPUTES (OCT 1995), ALTERNATE I (DEC 1991)
I.059 FAR 52.233-3 -- PROTEST AFTER AWARD (AUG 1996) AND ALTERNATE I (JUN 1985)
I.060 DEAR 952.235-70 -- KEY PERSONNEL (APR 1995)
I.061 FAR 52.242-1 -- NOTICE OF INTENT TO DISALLOW COSTS (APR 1984)
I.062 FAR 52.242-3 -- PENALTIES FOR UNALLOWABLE COSTS (OCT 1995)
I.063 FAR 52.242-13 -- BANKRUPTCY (JUL 1995)
I.064 FAR 52.242-15 -- STOP-WORK ORDER -- ALTERNATE I (AUG 1989)
I.065 FAR 52.243-2 -- CHANGES (COST-REIMBURSEMENT) ALTERNATES I AND V (AUG 1987)
I.066 FAR 52.244-2 -- SUBCONTRACTS (COST-REIMBURSEMENT AND LETTER CONTRACTS) (MAR 1996)
I.067 FAR 52.244-5 -- COMPETITION IN SUBCONTRACTING (DEC 1996)
I.068 FAR 52.244-6 -- SUBCONTRACTS FOR COMMERCIAL ITEMS AND COMMERCIAL COMPONENTS (OCT 1995)

I.069 DEAR 952.245-5 -- GOVERNMENT PROPERTY -- COST-REIMBURSEMENT, TIME-AND-MATERIAL, OR LABOR-HOUR CONTRACTS) (JAN 1986)
I.072 FAR 52.246-8 -- INSPECTION OF RESEARCH AND DEVELOPMENT (COST-REIMBURSEMENT) BASIC AND ALTERNATE I APR 1984)
I.074 FAR 52.247-63 -- PREFERENCE FOR U.S.-FLAG AIR CARRIERS (JAN 1997)
I.075 FAR 52.247-64 -- PREFERENCE FOR PRIVATELY OWNED U.S.-FLAG COMMERCIAL VESSELS (JUN 1997)
I.078 FAR 52.249-6 -- TERMINATION (COST-REIMBURSEMENT) (SEP 1996)
I.079 FAR 52.249-14 -- EXCUSABLE DELAYS (APR 1984)
I.080 DEAR 952.251-70 -- CONTRACTOR EMPLOYEE TRAVEL DISCOUNTS (JUN 1995)
I.081 FAR 52.252-2 -- CLAUSES INCORPORATED BY REFERENCE (JUN 1988)
I.083 FAR 52.227-1 -- AUTHORIZATION AND CONSENT ALTERNATE I (APR 1984)
I.084 FAR 52.227-2 -- NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT (AUG 1996)
I.085 DEAR 952.227-9 -- REFUND OF ROYALTIES (FEB 1995)
I.086 DEAR 952.227-11 -- PATENT RIGHTS -- RETENTION BY THE CONTRACTOR (SHORT FORM) (FEB 1995)
I.087 DEAR 952.227-13 -- PATENT RIGHTS -- ACQUISITION BY THE GOVERNMENT (MAR 1995)
I.088 FAR 52.227-14 -- RIGHTS IN DATA -- GENERAL WITH ALTERNATES I AND V (JUN 1987)
I.089 FAR 52.227-16 -- ADDITIONAL DATA REQUIREMENTS (JUN 1987)
I.091 FAR 52.227-23 -- RIGHTS TO PROPOSAL DATA (TECHNICAL) (JUN 1987)

PART II -- SECTION IA

CONTRACT CLAUSES

The following additional contract clauses are also incorporated by reference.

IA.025	FAR 52.215-39 -- REVERSION OR ADJUSTMENT OF PLANS FOR POSTRETIREMENT BENEFITS OTHER THAN PENSIONS (PRB) (MAR 1996)
IA.041	FAR 52.220-4 -- LABOR SURPLUS AREA SUBCONTRACTING PROGRAM (APR 1984)
IA.068	FAR 52.230-2 -- COST ACCOUNTING STANDARDS (AUG 1992)
IA.069	FAR 52.230-3 -- DISCLOSURE AND CONSISTENCY OF COST ACCOUNTING PRACTICES (NOV 1993)
IA.070	FAR 52.230-4 -- CONSISTENCY IN COST ACCOUNTING PRACTICES (AUG 1992)
IA.071	FAR 52.230-5 -- ADMINISTRATION OF COST ACCOUNTING STANDARDS (FEB 1995)
IA.111	FAR 52.253-1 -- COMPUTER-GENERATED FORMS (JAN 1991)
IA.112	FAR 52.242-4 -- CERTIFICATION OF INDIRECT COSTS (JAN 1997)

J.000a LIST OF DOCUMENTS, EXHIBITS, AND OTHER ATTACHMENTS (CONTRACTS)

Attachment	Description
A	Objectives/Background/Expected Results
A1	Statement of Work Sample Exhibit I- NEPA Attachment
A2	Massachusetts Institute of Technology Final Report Titled "CO_2 Capture, Reuse, and Storage Technologies for Mitigating Global Climate Control"
B	Reporting Requirements
C	List of Government Property -- Contractor Acquired
D	Intention to Propose*
E	Standard Form (SF) 1411*

*It is recommended that the offeror print these forms out prior to completing as the documents are not set up to accept input. The documents are also located in individual files on this diskette.

STATEMENT OF WORK

Program Research and Development Announcement
No. DE-RA26-98FT35008

GLOBAL CLIMATE CHANGE -
NOVEL CONCEPTS FOR MANAGEMENT OF GREENHOUSE GASES

A. OBJECTIVES

This procurement will support the development of novel, low cost concepts to recover, sequester or provide for the direct utilization of greenhouse gases. The greenhouse gases of interest are CO_2, CH_4 and N_2O, and are usually associated with the production and use of fossil fuels. Low cost concepts are sought that are broadly applicable to the utilization of fossil fuels (coal, natural gas, and oil) that would reduce emissions (below those resulting from improvements or advances in system cycle efficiencies), that provide for reuse or production of valuable byproducts, and that provides innovative long-term storage or disposal of greenhouse gases.

The program is structured to consist of three Phases that represent small-scale studies validating the concept feasibility(e.g., fundamental studies, computational analysis, laboratory studies), leading to process development studies (e.g., bench-scale to PDU), followed by proof-of-concept field or pilot plant studies. It is anticipated that numerous studies will be selected for Phase I participation, followed by a competitive selection for Phase II efforts, and finally, the most promising concepts proceeding to a Phase III effort based on a competitive selection.

Respondents to this solicitation are anticipated to range from entrepreneurs, universities, small and large businesses (private or public), and industrial research professionals.

B. BACKGROUND

In June 1992, at the Earth Summit in Rio de Janeiro, the United States (U.S.) signed the Framework Convention on Climate Change (FCCC). The U.S. Senate ratified the treaty in August 1992. Under the treaty, industrialized countries are to quantify greenhouse gas emissions and describe plans to reduce these emissions to 1990 levels by the year 2000. In October 1993, the Climate Change Action Plan describes the steps the U.S. would take to stabilize greenhouse gas emissions. At the end of 1996, the U.N.-sponsored Intergovernmental Panel on Climate Change (IPCC) stated that “the balance of evidence suggests a discernible anthropogenic influence on climate change.”

In the short-term, the Department of Energy’s Office of Fossil Energy (FE) is responding to climate change concerns by pursuing programs in energy efficiency. However, now that the U.S. and international community are starting to look well beyond the year 2000, additional greenhouse gas mitigation technologies may be required. Thus, FE must begin to seriously investigate the continued use of fossil fuels together with the application of futuristic technologies for carbon sequestration and recycling. For the

purposes of this solicitation, sequestration is a very broad term which encompasses a variety of ways to recover, and store the gas, or the carbon from the gases, in a form that shall remain stable for centuries. Recycling refers to the ability to reuse carbon.

In July 1993, the Massachusetts Institute of Technology (MIT) evaluated and prioritized research needs for the recovery, utilization, and disposal of CO_2 from fossil fuel-fired power plants (Herzog). Other studies (Doctor) have concluded that substantial energy and economic penalties would be associated with the use of currently available technology for carbon sequestration. The International Energy Agency Greenhouse Gas Research and Development Programme (IEA GHG RD), an international collaborative program, has also performed extensive evaluations of a wide variety of technologies for reducing greenhouse gas emissions arising from the use of fossil fuels.

The above studies have concluded that substantial energy and economic penalties would be associated with the use of currently available technology for carbon sequestration (as great as 40% efficiency reduction and doubling of electricity prices). In addition, the technical, economic, and environmental feasibility of an acceptable suite of land-based and ocean-based carbon sequestration options have yet to be proven. In the United States, very little research and development has been done on promising options which might address these problems. Such approaches might integrate CO_2 removal with advanced energy conversion processes which facilitate low energy recovery of CO_2. Furthermore, the total industrial use of CO_2 in the U.S. is about 40 million tons per year, equivalent to about 2% of total annual power plant CO_2 emissions. The challenge is to find new and expanded applications that utilize CO_2 in a non-energy intensive manner. For example, a variety of intriguing carbon recycling approaches have been suggested using natural and artificial photosynthesis to produce clean fuels such as methanol and hydrogen from carbon dioxide and water.

Thus, it appears that substantial advances may be possible through the discovery of new advanced and innovative technology, concepts, methods, or systems that until now are undeveloped or considered unsuitable for current application. Innovation is defined as the process of introducing new ideas into use, or the process of introducing novel uses of existing ideas. Therefore, FE is interested in developing effective and low-cost “path-breaking” technology.

Substantial advances are needed in fundamental understanding leading to process developments and integration in system configurations to support the development of new innovative technology or improvements to existing methods or systems that are presently considered unsuitable for current application. Therefore “path-breaking” technology developments are needed to recover, sequester, or develop direct utilization processes at low or minimal cost to industry and consumers.

Support for the development of novel or “breakthrough” technology will be a coordinated effort between the DOE’s Office of Fossil Energy, Office of Energy Efficiency and Office of Energy Research.

References

H. Herzog, E. Drake, J. Tester, Energy Laboratory, Massachusetts Institute of Technology, “A Research Needs Assessment for the Capture, Utilization and Disposal of Carbon Dioxide from Fossil Fuel-Fired Power Plants,” - Volume 1. Executive Summary: Final Report; Volume 2. Final Report, U.S. Department of

Energy, July, 1993. (Report Nos. DOE/ER-30194-Vol.1 and DOE/ER-39194-Vol.2) (NTIS Order Nos. DE94002377 and DE94002378), NTIS Telephone No. (703) 487-4700.

R. Doctor, J. Molburg, P. Thimmapuram, Argonne National Laboratory, "KRW Oxygen- Blown Gasification Combined Cycle: Carbon Dioxide Capture, Transport, and Disposal," August 1996, (NTIS Order No. DE96014951), NTIS Telephone No. (703) 487-4700.

IEA GHG RD Programme reports available at http://www.ieagreen.org.uk/ : GHG Emissions from Power Stations (SR1-P), Capture of CO2 from Power Stations (SR2-P), CO2 Disposal from Power Stations (SR3-P), CO2 Utilization (SR4-P), Global Warming Damage and the Benefits of Mitigation (SR5-P), Technical Responses to Climate Change (SR6-P).

C. SCOPE OF WORK

The proposed work should address the development of low-cost concepts to recover, sequester or provide for the direct utilization of greenhouse gases. The work shall develop novel and innovative, "path-breaking" concepts that are beyond current evolutionary development, in addition to significant improvements in existing technology. The proposed work should proceed on the developmental pathway to a degree sufficient to validate the concepts at an engineering scale.

The innovative concepts include novel, undeveloped, potentially low-cost methods and systems for sequestering greenhouse gases which include ways to recover, recycle, or store greenhouse gas or their conversion products. The potentially low-cost concepts must also have potential to reduce emissions well below those resulting from increased efficiency of fossil-fuel use. The concepts can include chemical or biological conversion methods, as well as physical storage. The greenhouse gas species of interest, $C0_2$, CH_4 and N_2O, are associated with the production and use of fossil fuels. Fundamental work prior to development of path-breaking technology may be included within the scope of the work. Such innovative technologies to be worth pursuing must have the ability to make significant improvements in cradle-to-grave system efficiency, energy consumption, greenhouse gas avoidance, and environmental impact.

Sequestration is meant in very broad terms to encompass a variety of ways to recover or store the gas or the carbon from the gases, in a form that will remain stable for centuries. Recycling refers to the ability to reuse carbon contained in fossil fuels.

Phase I tasks include: 1) Technical and preliminary economic assessment of the proposed concept as to the feasibility of the proposed technology, which may include small-scale experimental studies to support the assessment; 2) The preparation of a topical report summarizing the results of the assessment; and 3) The preparation of a proposed work plan with costs and schedule (proposal) to further develop the concept in optional Phase II.

Phase II tasks include: 1) Small scale engineering or laboratory studies supporting development of the proposed technology concept; 2) Scale-up of studies to verify feasibility at a larger or bench-scale level; 3) A conceptual economic and engineering evaluation of full-scale implementation; 4) The preparation of a topical report summarizing the results of the Phase II activity; and 5) The preparation of a proposed work plan with costs and

schedule (proposal) to further demonstrate the concept at larger scale in optional Phase III.

Phase III tasks include: 1) Scale-up of experimental studies up to pilot-scale, slip-stream, or field tests to verify engineering and process operations and integration; 2) Conduct of an indepth economic and engineering evaluation of full-scale commercial application; and 3) Transfer of the technology to a U.S. industrial party.

D. TASKS TO BE PERFORMED

Phase I -- Evaluate Merit and Feasibility of Concept. At the conclusion of Phase I studies, conduct an evaluation of the merit and feasibility of proposed concepts supporting Phase II work as follows:

> Task 1.1 -- Assessment. The offeror shall evaluate the technical merit and the potential impact in terms of applicability to a large number of sites and quantity (tons) of greenhouse gases that would be recovered or sequestered, and the feasibility of the proposed concept for the development of path-breaking, less costly means to addressing greenhouse gas emissions. If fundamental scientific knowledge and understanding is required, the offeror shall assess how the knowledge can serve as a basis for the development of path-breaking technologies to reduce greenhouse gas emissions. The offeror shall provide a preliminary cost of the technology applied at a selected site.
>
> Task 1.2 -- Work Plan for Phase II. Two months prior to the conclusion of Phase I, the offeror shall prepare a revised proposal for Phase II according to the Guidelines for Offerors provided in the solicitation. The proposal must describe or identify decision points that can be used to assess technical results validating the proposed concept, and progress toward the timely completion of Phase II. The results shall support the proposed Phase II activity, including technical approach, cost, and schedule. The offeror shall provide a detailed discussion of the offeror's plan for the conduct of the project for the Phase II activity.
>
> Task 1.3 -- Topical Report. One month prior to the end of Phase I, the contractor shall prepare a draft topical report that details the results and accomplishments to date. The Government shall have two weeks to comment on the draft report. The contractor shall incorporate the comments and finalize the draft by the end of Phase I. The topical report will be deemed to be the final report if the project is not selected for support in Phase II.

Phase II -- Verification of Process Feasibility. If selected for further support, the contractor shall proceed according to the revised proposal for Phase II activities submitted in Task 1.2.

Phase III -- Verification of Engineering and Process Operations and Integration. If selected for further support, the contractor shall proceed according to the proposed Phase III work plan proposal submitted 2 months prior to the conclusion of Phase II.

THE STATEMENT OF WORK IS LIMITED TO SEVEN (7) PAGES

Offerors shall prepare the Statement of Work in the following format:

Title of Work to Be Performed:

Insert title of work to be performed. Be concise and descriptive (e.g., "Road Transportable Analytical Laboratory Systems"). The title should correlate with the greenhouse gases of interest.

A. Objectives

Include one paragraph on the overall objective(s) of the work. Include objectives for the Phase I (Technical and Preliminary Economic Assessment), Phase II (Small Scale Engineering or Laboratory Studies), and Phase III (Scale-Up of Experimental Studies up to Pilot-Scale, Slip-Stream, or Field Tests).

B. Scope of Work

This section should not exceed one-half page and should summarize the effort and approach to achieve the objective(s) of the work.

C. Tasks to be Performed

Tasks, concisely written, should be provided in a logical sequence and should be divided into three phases: Phase I, Phase II, and Phase III. Each phase, and task within a phase, should be numbered and titled. In addition, each phase should be independent, with a decision point at the completion of Phase I whereby the DOE can make a competitive down selection process occurring at the completion of Phases I and II.

Note that all Offerors are required to include Task 1, "Information Required for the National Environmental Policy Act," in the SOW.

Task 1. Information Required for the National Environmental Policy Act

The contractor shall prepare a draft report which provides the environmental information described in Exhibit I, "Required Information For The National Environmental Policy Act (NEPA)." This information will be used by the DOE to prepare the appropriate level of NEPA documentation for the project.

Until the NEPA review and approval process is completed and written notification is provided by the contracting officer, the contractor shall take no action that would have an adverse impact on the environment or limit the choice of reasonable alternatives to the proposed action. The contractor is not precluded from planning, developing preliminary designs, or performing other work necessary to support an application for Federal, state, or local permits.

D. Deliverables

Provide a list of deliverables other than those identified in the Reporting Requirements Checklist (Part III, Section J, Attachment B to the sample contract). Additional reports will include, but are not limited to: Topical Reports, Contractor Review Meeting Reports, and Technical Presentation papers.

E. Briefings

Provide a list of project briefings including purpose, schedule, location, and number of travelers. The contractor should anticipate developing a technical paper and making a presentation at a DOE Contractor Review Meeting at the Federal Energy Technology Center.

EXHIBIT I
INFORMATION REQUIRED FOR THE NATIONAL
ENVIRONMENTAL POLICY ACT (NEPA)

The following is a description of the environmental, safety, and health (ES&H) information to be provided by the contractor to enable DOE to prepare the appropriate NEPA documentation for the proposed project. The ES&H information shall include, but is not limited to:

1.0 Brief, nonconfidential description of the project including project objectives, project schedule, summary of test plans, map location(s), description of existing facilities, and description of facilities to be constructed for the project. If appropriate, the contractor should provide process flow diagrams, and plan and elevation views. The contractor should provide sizes and capacities for major equipment. A discussion should be included on the quantities and types of materials to be used in the project including feedstocks, utilities, fuels, reactants, products, effluents, unrecovered materials, and solid waste.

2.0 Discussion regarding current environmental characteristics of the site(s) and any potential environmental impacts from the project. Information on environmental impacts should provide data in terms of minimum, maximum, and average values rather than qualitative statements, such as "insignificant" or "minimal," which are subject to interpretation. Include discussion regarding compliance with Federal, state, and local environmental regulations. The following is a list of potential environmental impacts to be included in the discussion.

Air Quality -- Include discussion regarding potential environmental impact from the seven criteria pollutants in the Clean Air Act (i.e., sulfur oxides, nitrogen oxides, carbon monoxide, hydrocarbons, particulate matter less than 10 microns (i.e., PM_{10}), lead, and ozone) and the Hazardous Air Pollutants (i.e., air toxics) list in the 1990 Title III amendment to the Clean Air Act. Discuss other potential air pollutants including carbon dioxide, volatile organic carbon, volatile metal compounds, and radioactive materials. Include air emission rates, pollutant emission rates, and duration of emissions.

Water Resources -- Include discussion regarding potential environmental impact to surface and ground waters. Include changes to water quality and quantity. The uses of the surface and ground waters should be included in the discussion. The discussion should include sources of water supply (e.g., public water supply or dedicated well) and any National Pollutant Discharge Elimination System (NPDES) permit(s). Include discussion regarding on-site treatment of wastewater. Include discussion regarding compliance with local, state, and Federal environmental regulations. Discuss status of local, state, and Federal permits for water use and discharges. Describe any stream diversions caused by construction activities. Discuss potential for surface and groundwater water to be contaminated by organics, heavy metals, radioactive materials, and other hazardous substances.

Land Use -- Include discussion on the amount of land at the existing site and the amount that will be used for construction of the project. The discussion should include the current use of the land, zoning requirements, and current access to the land. A discussion should be included on the uses and zoning of surrounding property. The discussion should include any modifications needed for access to the land as a result of the project. Include discussion on impacts to visual and aesthetic values.

Waste Management -- Include discussion on solid and liquid waste management including waste characteristics, quantities, pretreatment, storage, transportation, and disposal practices. Identify any potentially hazardous waste materials. Include any results from analyzing solid waste in accordance with the Resource Conservation and Recovery Act characterization tests. Include discussion regarding compliance with Federal, state, and local environmental regulations. Discuss status of Federal, state, and local permits. Discuss storage, treatment, and disposal of any radioactive materials.

Ecological Impacts -- Include a discussion regarding potential environmental impacts to vegetation, terrestrial wildlife, aquatic wildlife, threatened and endangered species, critical habitats, floodplains, and wetlands.

Socioeconomic Impacts -- Include information regarding availability of labor for the project, availability of transportation, and any potential impact on public services. Include information on impact to visual or aesthetic quality.

Archaeological, Cultural, and Historical Resources -- Include information regarding contacts with state agencies to assess project impact on archaeological, cultural, and historically significant resources.

Noise -- Include a discussion on possible environmental impacts from noise generated by the project. Include a discussion on current noise levels and any possible increases in noise levels from the project. In general, the noise level is measured at the nearest point of public access. Include a discussion regarding proximity and any possible impact to noise-sensitive sites such as schools, hospitals, and nursing homes.

Occupational Safety and Health -- Include a discussion on plans to protect worker safety and health on the project (e.g., clothing, hearing protection, operating practices). If the project presents a potential safety hazard beyond the project boundaries, emergency response plans should be included in the discussion. Include information on compliance with Occupational Safety and Health Act and facility designs related to mitigation of occupational impacts. Discuss hazards and mitigation measures related to construction activities and exposure to hazardous substances, heat, noise, and odor. Discuss worker protection equipment and procedures in potentially radioactive environments.

Cumulative Impacts -- The cumulative impact is the impact to the environment which results from the incremental impact from the proposed action when added to impacts from past,present, and

reasonably foreseeable future actions. Individual impacts may be minor, but the combined impact (i.e., cumulative) can be significant. Include a discussion on the contribution of environmental impacts from the proposed action to the cumulative impact. Each of the potential environmental impacts described above should be considered relative to their impact on the existing environmental setting and emissions. Generally, impacts which contribute to the cumulative impact include air emissions, water and liquid effluent treatment, solid waste management, and land use.

Summary of Environmental Impacts -- Include a factual summary of potential environmental impacts.

3.0 A table should be prepared that identifies all Federal, state, and local permits and licenses required for the project. The table should provide information on the permitting and licensing schedule and current status of each permit and license. A discussion should be included on the allowable releases of solid, liquid, and air pollutants under the permit(s) and license(s). Include any emission limits set by the Nuclear Regulatory Commission.

4.0 Provide complete addresses and phone numbers for agencies and persons contacted to collect information on the ES&H aspects of the project.

CO_2 Capture, Reuse, and Storage Technologies for Mitigating Global Climate Change

A White Paper
Final Report

DOE Order No. DE-AF22-96PC01257

Energy Laboratory
Massachusetts Institute of Technology
77 Massachusetts Avenue
Room E40-455
Cambridge, MA 02139-4307
Telephone:(617) 253-3401
Fax:(617) 253-8013

Howard Herzog, Elisabeth Drake, Eric Adams

January, 1997

Disclaimer

Acknowledgment

This White Paper was sponsored by the US Department of Energy, Office of Fossil Energy. The work, performed at the MIT Energy Laboratory, was directed by Howard Herzog who was also a principal author along with Eric Adams and Elisabeth Drake. It draws on earlier work sponsored by DOE (Herzog *et al.*, 1993), augmented by subsequent research most recently reported in the *Third International Conference on Carbon Dioxide Removal*, held at MIT in September 1996.

The authors greatly appreciate the guidance and helpful comments provided by Perry Bergman and Robert Kane of the Office of Fossil Energy, the primary technical monitors for the White Paper, and, also their coordination of a speedy and effective review effort both within and outside the DOE. The reviewers' comments were thorough and helpful in making the report as balanced and accurate as possible. Within DOE, reviewers included David Beecy, Charles Byrer, Douglas Carter, Charles Drummond, Philip Goldberg, Hugh Guthrie, Harvey Ness, Randolph Pennington, John Ruether, Lawrence Ruth, Dennis Smith, and Robert Warzinski. Outside reviewers included John Benemann, Consultant; Zhong-Ying Chen, SAIC; Paul Freund and colleagues at the IEA Greenhouse Gas R&D Programme; Jefferson Tester, MIT Energy Laboratory; and Edward Winter, Burns and Roe. Helpful background material was provided to us in particular topic areas by John Benemann (biomass options), Thomas Grahame of DOE (ocean fertilization), Elias Greenbaum of Oak Ridge National Laboratory (renewable hydrogen production), Klaus Lackner of the Los Alamos National Laboratory (carbonate storage) and Meyer Steinberg of Brookhaven National Laboratory (fuel conversion options).

Particular thanks go to Jeremy Levin, the MIT graduate student who provided considerable support in gathering and integrating background information and some of the quantitative data used in the report.

Table of Contents

1. Executive Summary

As the world's largest emitter of CO_2, the US needs to develop a balanced portfolio of responses that will allow us to be an effective participant in evolving international agreements to address climate change concerns. This "climate portfolio" needs to include activities on the various aspects of the climate change problem, including better understanding the science and the potential impacts, developing technological responses for adaptation and mitigation, and formulating policies that take into account the economic costs. The purpose of this white paper is to discuss an important opportunity which we should consider as part of our technological response, namely the capture and sequestration of CO_2 from large stationary sources.

In the short-term, the US Department of Energy (DOE) is responding to climate change concerns by pursuing programs to promote energy efficiency. For example, the Office of Fossil Energy (FE) has a program targeted at increasing the efficiency of fossil fuel-fired power plants. However, now that the US and the international community are starting to look beyond the year 2000, additional mitigation technologies may be required. FE can respond to this longer-term outlook by investigating the continued use of fossil fuels with technologies for CO_2 capture and sequestration. A five year program is recommended to investigate the feasibility of such technologies and to foster their development where appropriate.

In this white paper, we will first discuss the motivation for developing CO_2 capture and sequestration technologies (Chapter 2) and then provide some background information, looking at both the history and economics of this mitigation option (Chapter 3). Next, we review the major technological components -- capture technology (Chapter 4), geological storage (Chapter 5), ocean storage (Chapter 6), and direct utilization (Chapter 7). Chapter 8 looks at system integration and implementation issues. In Chapter 9 we look at some other CO_2 mitigation technologies that FE may want to consider investigating as part of an integrated program. Finally, specific recommendations for research are summarized in Chapter 10.

Because of the potential adverse impacts from global climate change, the world community has adopted the Framework Convention on Climate Change. The urgency of their work was recently underscored when the Intergovernmental Panel on Climate Change (IPCC) issued their *Second Assessment Report* which stated that "the balance of evidence suggests a discernible human influence on global climate". US Under Secretary of State Timothy Wirth has stated that the US will press for "an agreement that sets a realistic, verifiable, and binding medium-term emissions target" (Testimony before the US Senate Energy and Natural Resources Committee, Sept. 17, 1996).

In viewing the spectrum of responses to global climate change, there are a number of relatively low cost CO_2 mitigation technologies, sometimes termed "least regrets". They include improving energy supply and end-use efficiency, switching from coal or oil to gas where possible, forestation, and inexpensive renewable energy applications. The major drawback of this group of

technologies is their limited impact. They may be sufficient to meet short-term goals, but there is a general belief that they will not be able to solve the problem in the mid- and long-term. In light of their limited reduction potential, additional, but more costly mitigation technologies must be considered, specifically CO_2 capture and sequestration, nuclear power, and large-scale renewable energy production. All three of these mitigation technologies have the potential to substantially reduce CO_2 emissions at comparable costs, yet all three suffer impediments (e.g., nuclear must solve issues of safety and public acceptance and renewable energy costs must decrease). Since at least one of these options (if not all three) will be required to stabilize atmospheric levels of greenhouse gases in the mid- to long-term, it is prudent to examine all three. Compared with nuclear and renewable energy, the US research effort to-date with respect to technologies for CO_2 capture and sequestration has been minimal. Thus we should extend our efforts to understand CO_2 capture and sequestration technologies in order to better evaluate their potential and to reduce their associated costs and risks.

The main challenge regarding CO_2 capture technology is to reduce the overall cost by lowering both the energy and the capital cost requirements. While costs and energy requirements for today's capture processes are high, the opportunities for significant reductions exist, since researchers have only recently started to address these needs. One strategy that looks extremely promising is to combine CO_2 removal with advanced coal energy conversion processes that have features which will enable low energy intensive capture.

The major options for CO_2 storage are underground or in the ocean. Statoil is presently storing one million tonnes per year of CO_2 from Norwegian gas fields in an aquifer beneath the North Sea. A larger aquifer storage project may soon be undertaken by Exxon and Pertamina at their Natuna gas field in the South China Sea. Besides aquifers, geologic storage options include active oil wells (in connection with enhanced oil recovery), coal beds, and depleted oil and gas wells. The issues which need clarification include storage integrity and reservoir characterization. Ocean CO_2 disposal would reduce peak atmospheric CO_2 concentrations and their rate of increase by accelerating the ongoing, but slow, natural processes by which most current CO_2 emissions enter the ocean indirectly. The capacity of the ocean to accept CO_2 is almost unlimited, but there are questions that still need to be addressed about its effectiveness (how long will the CO_2 remain sequestered) and about the environmental impacts associated with increased seawater acidity near the injection point.

While there are diverse niche opportunities for industrial utilization of power plant CO_2, these uses are all small compared to the total quantities of CO_2 emitted by the power sector. Multiple small uses can be an effective, but small, part of a mitigation strategy. Large scale chemical conversion of power plant CO_2 to fuels such as methanol requires so much energy that it produces marginal mitigation benefit, if any. Microalgae offer the potential for conversion of power plant CO_2 to biomass, but research is needed to achieve improvements in productivity that would reduce land requirements and costs. Storage as carbonate minerals is another possibility, but materials handling and waste issues make practicality uncertain without further investigation. In the nearer term, limited biomass energy farming, coupled with cofiring of farmed or waste

biomass with fossil fuels is an attractive option. In the much longer-term, research on bioproduction of hydrogen or on artificial photosynthesis may provide new and significant pathways for mitigation.

To address the above challenges and opportunities, we propose an initial five year research program into the capture and sequestration of CO_2 with the following strategic goals: encourage/accelerate near-term opportunities, assess compatibility with on-going advanced combustion and efficiency programs, assess longer-term feasibility, position the US to become a technology leader, leverage on-going international research, and stimulate private sector R&D.

To date, the cumulative research dollars spent on CO_2 capture and sequestration technologies in the US has been less than $10 million, limiting the research effort to small theoretical or laboratory studies. To allow needed program development, we recommend a budget that averages $50 million per year for 5 years as detailed below:

FY98 $20 million
FY99 $40 million
FY00 $60 million
FY01 $70 million
FY02 $60 million

We envision leveraging this budget through collaboration with the private sector and through international collaboration. Approximately half of the funding should go towards collaborative projects. Specific program components, with their relative share of available funds indicated, are:

- Promotion of near-term opportunities (15%).
- Assessment and development of capture technology (25%).
- Assessment and development of storage technology (35%).
- System analysis (10%).
- Generation and assessment of longer-term technologies (15%).

To put this budget request in perspective, we can make the following comparisons:

- The limited funding to date for CO_2 capture and sequestration has not allowed significant program development, making it difficult to fairly assess the potential of these technologies compared to other longer-term CO_2 mitigation options for which substantial sums of money have been spent (e.g., switching to nuclear or renewable energy sources).

- The total US energy expenditures are approximately $500 billion annually, while the existing capital stock of the utility industry worldwide is estimated in excess of $2 trillion. It seems wise to investigate whether CO_2 capture and sequestration technologies can allow fossil fuels to remain a cost-effective energy source, while concurrently contributing to a significant reduction in greenhouse gas emissions.

- The proposed budget is modest in comparison to Japanese government expenditures on CO_2 capture and sequestration (by at least a factor of 2).

- The US now spends about $1.6 billion annually investigating various aspects of the climate change problem. Spending at that level indicates that global climate change is being taken seriously. It seems prudent to spend at just 3% of that level to investigate the flexibility of one of the few possible longer-term mitigation solutions.

2. Motivation and Overview

The purpose of this white paper is to discuss *new* opportunities for the US Department of Energy's Office of Fossil Energy (FE) to contribute to the solution of the climate change problem. It is important to emphasize that FE programs are already addressing a high priority opportunity for CO_2 mitigation -- increasing the efficiency of fossil fuel-fired power plants (see Appendix A). However, now that the US and the international community are starting to look beyond the year 2000, additional mitigation technologies may be required. FE can respond to this longer-term outlook by investigating the feasibility of technologies for CO_2 capture and sequestration and by fostering their development where appropriate.

Fossil fuels currently supply over 85% of the world's energy needs. They will remain in abundant supply well into the 21st century. They have been a major contributor to the high standard of living enjoyed by the industrialized world. We have learned how to extract energy from fossil fuels in environmentally friendly ways, controlling the emissions of NO_x, SO_2, unburned hydrocarbons, and particulates. Even with these added pollution controls, the cost of fossil energy generated power keeps falling.

Despite this good news about fossil energy, its future is clouded because of the environmental and economic threat posed by possible climate change, commonly referred to as the "greenhouse effect". The major greenhouse gas is carbon dioxide (CO_2) and the major source of anthropogenic CO_2 is combustion of fossil fuels. This white paper proposes a research agenda to assess and develop competitive technologies that will allow us to continue to enjoy the benefits of fossil energy while significantly reducing emissions of greenhouse gases.

The potential impacts of global climate change are many and varied, though there is much uncertainty as to the timing and magnitude (Watson *et al.*, 1996). Because of the potential adverse impacts, the world community has adopted the Framework Convention on Climate Change (see Box 1). The urgency of their work was recently underscored when the Intergovernmental Panel on Climate Change (IPCC) issued their *Second Assessment Report* which stated that "the balance of evidence suggests a discernible human influence on global climate". US Under Secretary of State Timothy Wirth has stated that the US will press for "an agreement that sets a realistic, verifiable, and binding medium-term emissions target" (Testimony before the US Senate Energy and Natural Resources Committee, Sept. 17, 1996).

One of the reasons for Secretary Wirth's statement is that international attempts to reduce emissions have proven inadequate to date. The goal of stabilization of greenhouse gas emissions at their 1990 levels in the year 2000 will not be met by the vast majority of countries. Based on this experience, it is obvious that more aggressive technology responses are required to control greenhouse gas emissions.

The US is promoting policies to produce responses that are cost-effective and flexible in both space and time. This approach was very successful in controlling SO_2 emissions, resulting in costs more than an order of magnitude lower than originally predicted. The research conducted on SO_2 control options contributed to this ultimate success. By analogy, to be able to control CO_2 in a cost-effective manner in the future, we need to do research today on possible technological responses. The flexibility in time is needed for both an economical turnover of the existing capital stock and to develop appropriate low-cost responses (Richels and Edmonds, 1995).

Since this is a global problem, flexibility in choosing the location for mitigation programs is very appropriate. Recovering a ton of CO_2 in China or anywhere else in the world is equivalent to recovering a ton in the US. This is the principle behind the development of Activities Implemented Jointly (AIJ)[1]. While the industrialized world has been the major emitter of CO_2 to date (with the US being the largest at about 20% of the world total), countries such as China and India will be the leading emitters in the 21st century. It should be noted that both these countries are planning to utilize their large coal reserves to help develop their economies.

At this point in time, there is too much uncertainty to predict what the best technological response should be. The uncertainty lies in the science of global climate change (e.g., what is the magnitude of the problem?), the form of the policy responses, and the cost and effectiveness of the mitigation technologies themselves. However, despite the uncertainties, it is still possible to make the following statements:

- No one category of mitigation technologies will solve the problem by itself. A multi-option approach will be required. The choice of specific options will depend on local circumstances.

- There are a number of categories of relatively low cost CO_2 mitigation strategies, sometimes termed "least regrets", that from an economic viewpoint could be implemented first. They include improving energy efficiency, switching from coal or oil to gas where possible, afforestation/reforestation, and inexpensive renewable energy applications. The major drawback of this group of technologies is their limited impact. They may be sufficient to meet short-term goals, but there is a general belief that they will not be able to address the problem in the mid- to long-term.

[1]The US Initiative on Joint Implementation (USIJI), initiated in October 1993 as part of the President's Climate Change Action Plan, is a program designed to encourage international private sector partnerships to reduce greenhouse gas emissions. Joint Implementation (JI) offers the potential to achieve greater and more cost effective emission reductions than would be likely if each country pursued only domestic actions. JI can also spur technology cooperation by increasing the market penetration of more efficient fossil generation and renewable technologies. JI projects also include fuel switching and reforestation projects. With the goal of testing criteria for joint implementation, the US supported the beginning of the international pilot phase of this program known as Activities Implemented Jointly (AIJ) at the first Conference of the Parties (COP-1) in April, 1995.

- To meet probable emissions targets in the mid- to long-term, more costly mitigation technologies must be considered, specifically CO_2 capture and sequestration, nuclear, and extensive use of renewable energy. All three of these technologies have the potential to significantly reduce emissions of CO_2, but there are limitations regarding their wide-spread implementation. As will be documented in this paper, CO_2 capture and sequestration has to reduce costs and demonstrate suitable methods of storage. Nuclear must address the issues of safety, waste, and public acceptance. Renewables have to overcome the problems of cost, intermittent supply, and limited geographical applicability.

Below are some reasons why research into CO_2 capture, use, and disposal technologies is important:

- It is a prudent measure since there are only a limited number of strategies to reduce greenhouse gas emissions. The field of CO_2 capture and sequestration is still in its infancy, with many questions needing to be addressed to make these technologies viable. At this time, it is judicious to explore all potential mitigation options in a balanced way, so that a broad range of strategies are available to help meet future policy goals.

- These technologies provide a long-term greenhouse gas mitigation option that allows for continued large-scale use of our abundant fossil energy resources.

- With continued research, these technologies have the potential to provide a cost-effective mitigation option in response to policies aimed at limiting greenhouse gas emissions and ultimately stabilizing greenhouse gas concentrations in the atmosphere.

- These technologies can be used as an alternate option in case new non-fossil energy sources like solar or present non-fossil energy sources like nuclear cannot gain sufficient market share and/or acceptance.

- These technologies could be a low cost mitigation option if hydrogen were to become a major energy carrier (see Chapter 4).

In this white paper, we will first review the background of CO_2 capture and sequestration, looking at both its history and economics (Chapter 3). Next, we review the major technological components -- capture technology (Chapter 4), geological storage (Chapter 5), ocean storage (Chapter 6), and direct utilization (Chapter 7). Chapter 8 looks at system integration and implementation issues. In Chapter 9 we look at some other CO_2 mitigation technologies that FE may want to consider investigating as part of an integrated program. Finally, specific recommendations for research are summarized in Chapter 10.

Box 1. International Activities on Climate Change

December 21, 1990	The Intergovernmental Negotiating Committee (INC) created by the United Nations. Negotiations begin on a climate treaty.
June, 1992	The Framework Convention on Climate Change (FCCC) adopted by 143 countries in Rio at the "Earth Summit". Among its provisions is a goal to stabilize greenhouse gases at their 1990 levels by the year 2000.
March 21, 1994	The FCCC comes into force 90 days after its ratification by 50 countries, including the United States.
March, 1995	The first Conference of the Parties (COP-1) to the FCCC held in Berlin. The Climate Technology Initiative (CTI) is adopted. One of its provisions is to "assess the feasibility of developing longer-term technologies to capture, remove or dispose of greenhouse gases and strengthen relevant basic and applied research."
February, 1996	CTI Task Force 7 formed to accelerate international collaboration for R&D in the field of medium- and long-term technologies relating to greenhouse gas capture and disposal.
June 5, 1996	The Intergovernmental Panel on Climate Change (IPCC) *Second Assessment Report* states that "the balance of evidence suggests a discernible human influence on global climate".
July, 1996	COP-2 held in Switzerland. US Under Secretary of State Timothy Wirth states that the US will press for an "agreement that sets out a realistic, verifiable, and binding medium-term emissions target."
November, 1996	In Australia, President Clinton calls "upon the community of nations to agree to legally binding commitments to fight climate change. We must stand together against the threat of global warming. A greenhouse may be a good place to raise plants; it is no place to nurture our children." (*Washington Post*, Nov. 23, 1996)
December, 1997	COP-3 scheduled to be held in Japan. On the agenda: emissions targets and timetables.

3. Background

For the capture and sequestration of CO_2, the most cost-effective targets are large stationary sources of CO_2, such as fossil fuel-fired power plants. These power plants produce about one-third of US CO_2 emissions in the production of electricity for residential, commercial, and industrial customers. This share may increase in the future due to continued electrification of the industrial and building sectors. Also, over the longer-term, even the transportation sector may be electrified.

Avoidance of CO_2 emissions through physical capture of CO_2 from fossil fuel power plants was first proposed by Marchetti (1977), with disposal of the captured CO_2 in the deep ocean. In the US, preliminary studies were conducted at Brookhaven National Laboratory (Albanese and Steinberg, 1980; Steinberg, 1984). However, it was not until almost 1990 that significant research efforts were undertaken in this field. Since then, many studies have been carried out and a number of conferences have been held on options for the capture and disposal or reuse of CO_2 from large stationary sources.

The first gathering of the international research community investigating CO_2 control technologies occurred in March 1992, at the First International Conference on Carbon Dioxide Removal (ICCDR-1) (Blok *et al.*, 1992). Held biennially, ICCDR-2 was organized by the Research Institute of Innovative Technology for the Earth (RITE) in Kyoto, Japan in October, 1994 (Kondo, *et al.*, 1995). Most recently, ICCDR-3 was organized by the Massachusetts Institute of Technology (MIT) Energy Laboratory with major sponsorship from the US Department of Energy (DOE) and the Electric Power Research Institute (EPRI). As in prior meetings, over 250 delegates from over 20 countries participated. The next gathering will be in Switzerland in 1998. This conference series is now a well established forum for the exchange of scientific and technical information on this rapidly advancing field of research.

The IEA Greenhouse GAS R&D Programme. In 1991, the International Energy Agency (IEA) established an Implementing Agreement for a research and development (R&D) program for greenhouse gas technologies. Initially, this program focused on analyzing technologies for capturing, utilizing, and storing of CO_2. The program is currently in its second 3-year phase, with support from 16 countries (including the US) and a number of commercial organizations (Webster, 1995). The scope of the program now includes other greenhouse gases (e.g., methane) as well as CO_2. The operating agent is the CRE Group Ltd. in Cheltenham, UK. As part of this program, two major conferences on CO_2 capture and disposal were held (Riemer, 1993; Riemer and Smith, 1996). Over 30 technical reports have been issued on a wide spectrum of subjects. The budget for phase 2 of this program is about one million dollars per year, with a US contribution of $180,000 per year. Plans for phase 3 are under discussion, including a proposal for the programme to facilitate the formation and management of collaborative research projects by member countries.

The Japanese research program. The largest research program on CO_2 capture and sequestration belongs to Japan. Japan's interest in this area is twofold -- first a genuine concern for the global environment, but also an interest to develop commercial technologies which they can market worldwide. Since 1990, the Japanese government has spent 39 billion yen (about $350 million) on research. The focus of Japan's research in CO_2 fixation and utilization is RITE (Research Institute of Innovative Technology for the Earth). Established in July 1990 and subsidized by MITI (Ministry of International Trade and Industry), RITE is an international center for research and communication. Two large projects just being completed by RITE are CO_2 fixation by microalgae ($123 million) and catalytic hydrogeneration of CO_2, which includes research on selectively permeable membranes for CO_2 capture ($77 million) (Myers, 1992). A new project of similar magnitude on ocean storage of CO_2 is due to start in April, 1997. MITI also funds research through a system of national laboratories administered by the Agency of Industrial Science and Technology (AIST). Finally, the government also supports university research in this field.

In addition to government programs, the private sector, including electric power companies, gas companies, and heavy industries (e.g., Mitsubishi, Hitachi, IHI), has significant research programs for CO_2 fixation and utilization. Additional research is being conducted at the Central Research Institute of the Electric Power Industry (CRIEPI).

The Japanese research program into CO_2 fixation and utilization is very comprehensive. There are research projects in a variety of programs including CO_2 capture/cycle modifications, ocean storage, geological storage, and utilization. Ocean storage is important to Japan because of their close proximity to the deep ocean and lack of geological storage options.

The US research program. The US research effort into CO_2 capture and sequestration technologies has spent about $10 million since 1989. The current level of funding is about one to two million dollars per year. This amount is extremely small compared to the total annual expenditure on global change research of $1.6 billion, most of which goes to understanding the science of climate change. However, the US has made significant contributions to the field, including a very well received research needs assessment. The US DOE (Fossil Energy and Energy Research) contracted with the MIT Energy Laboratory to identify, assess, and prioritize research needs for the capture and non-atmospheric sequestration of a significant portion of the CO_2 emitted from fossil fuel-fired electric power plants (Herzog *et al.*, 1993). While much new knowledge has been gained since that time, the conclusions still provide a useful starting point for further analysis (see Box 2). An update of this assessment is currently underway.

Current Status. Today the two key challenges that must be addressed by the international research community investigating CO_2 removal technologies are reducing costs and finding suitable methods of sequestration. While there is much work to do, results to date give reasons for optimism.

Concerning the issue of cost, it should be noted that specific policy options aimed at reducing CO_2 emissions to the atmosphere are required before CO_2 capture and sequestration technologies can compete with other technological options in the marketplace. As noted in Chapter 2, international negotiations are now moving in this direction. At ICCDR-3, considerable progress was reported on technical research that could significantly lower costs to the levels required for the CO_2 capture option to successfully compete with other potential mitigation options such as renewable or nuclear energy substitutes (see Chapter 4). More discussion of the costs of CO_2 capture and sequestration is presented at the end of this chapter.

Since only 1-5% of the total CO_2 emissions from power plants could be reused effectively, technically feasible and publicly acceptable storage options are required. Two major projects, one operational and one planned, will go a long way toward demonstrating technical feasibility of large-scale storage:

- In September 1996, Statoil of Norway began storing CO_2 from the Sleipner West gas field into a sandstone aquifer 1000 m beneath the North Sea. The CO_2 is injected from a floating rig through five pipes at a rate of 20,000 tonnes/week (corresponding to the rate of CO_2 produced from a 140 MW_e coal fired power plant). Earlier pilot studies showed that most of the CO_2 will react to form solid calcite, with some dissolving in the groundwater and some remaining as a separate phase. While Statoil has not disclosed information on the project costs, they have stated that the cost is less than the Norwegian carbon tax of $50 per tonne CO_2. An international research effort is being organized to monitor and document this effort so the experience can be built on by future endeavors.

- Exxon and Pertamina have recently announced plans to inject CO_2 from their natural gas field at Natuna into a deep aquifer 1000 m below the South China Sea floor, 375 miles east of Singapore (*Boston Globe*, p. 33, Nov. 20, 1995). Natural gas from the reservoir, one of the world's largest, will be liquefied to produce LNG for sale to the Far East, but it contains over 70% CO_2 by volume which must first be separated and sequestered. Averaged over a 30 year period, the 150 trillion cubic feet (about 4 trillion cubic meters) of stored carbon dioxide corresponds to the volume emitted through continuous production of 38,000 MW_e of electricity from coal fired power plants.

Comparison to other CO_2 mitigation options. In viewing the spectrum of responses to global climate change, there are a number of relatively low cost CO_2 mitigation technologies, sometimes termed “least regrets”. They include improving energy supply and end-use efficiency, switching from coal or oil to gas where possible, forestation, and inexpensive renewable energy applications. The major drawback of this group of technologies is their limited impact. They may be sufficient to meet short-term goals, but there is a general belief that they will not be able to solve the problem in the mid- and long-term. In light of their limited reduction potential, additional, but more costly mitigation technologies must be considered, specifically CO_2 capture and sequestration, nuclear power, and extensive use of renewable energy. All three of these

technologies have the potential to substantially reduce CO_2 emissions. These points are illustrated by the data presented in Table 1. However, it is important to understand the basis and limitations of these data (see Appendix B for more details)[2]:

- For nuclear, renewable, and "least-regrets" technologies, we relied heavily on a National Academy Study (NAS, 1992), whose numbers were based on an extensive literature review. The study involved about 50 experts from academic, industrial, governmental, and public interest organizations. We supplemented the data with additional sources, which we evaluated on a comparable basis.

- For CO_2 capture and sequestration, we calculated the numbers based on inputs from the existing literature.

- For "least-regrets", we only considered technology as it exists today. For the other categories which are being considered for the mid- to long-term, we also made additional estimates for the year 2010 assuming advances over today's technology through research.

The data presented contain a great deal of uncertainty as seen by the large range in estimated costs and, therefore, should be used with discretion. However, the data are sufficient to support an important conclusion: the current and projected costs of CO_2 capture and sequestration technologies are comparable to the costs for nuclear or renewable energy options (see Figure 1). Since at least one of these options (if not all three) will be required to stabilize atmospheric levels of greenhouse gases in the mid- to long-term, it is prudent to examine all three. Compared with nuclear and renewable energy, the US research effort to-date with respect to technologies for CO_2 capture and sequestration has been minimal. Thus we should extend our efforts to understand CO_2 capture and sequestration technologies in order to better evaluate their potential and to reduce their associated costs and risks. In the chapters that follow, we document the current understanding of CO_2 capture and sequestration technologies and highlight some key research needs.

[2]Except for CO_2 capture and sequestration technologies, it was beyond the scope of this project to fully evaluate the costs of the mitigation technologies presented in Table 1. Therefore, we had to rely on published studies in the literature. These studies were highly dependent on the assumptions used. We feel that more work needs to be done in generating a consistent set of generally accepted mitigation cost data. However, despite their shortcomings, the data presented in Table 1 are of sufficient quality to support our general conclusions.

Table 1. Potential and Cost of Various CO_2 Mitigation Options for the US (see Appendix B for sources and other details)

CO_2 Mitigation Option	**Reduction Potential (million tonnes CO_2)**	**Net Cost (1990 $) ($/tonne CO_2 avoided)**	
CO_2 capture and sequestration technologies			
		High	*Low*
Capture with utilization	20	5	0
Capture with enhanced oil recovery	50	45	10
Capture (industrial sources) with storage	80	76	24
Capture with geological storage	900	91	31
Capture with ocean storage	600	91	31
Energy supply technologies			
		High	*Low*
Nuclear	1500	61	13
Hydroelectric	30	38	25
Biomass	130	42	8
Geothermal	69 - 235	144	0
Wind	30	125	0
Solar photovoltaic	400	400	23
Solar thermal	540	178	24
"Least-regrets" options			
		High	*Low*
Energy (end-use) efficiency	425 - 620	6	-84
Supply efficiency	99	2	0
Fuel switching to gas	850	46	17
Forestation	242	10	3

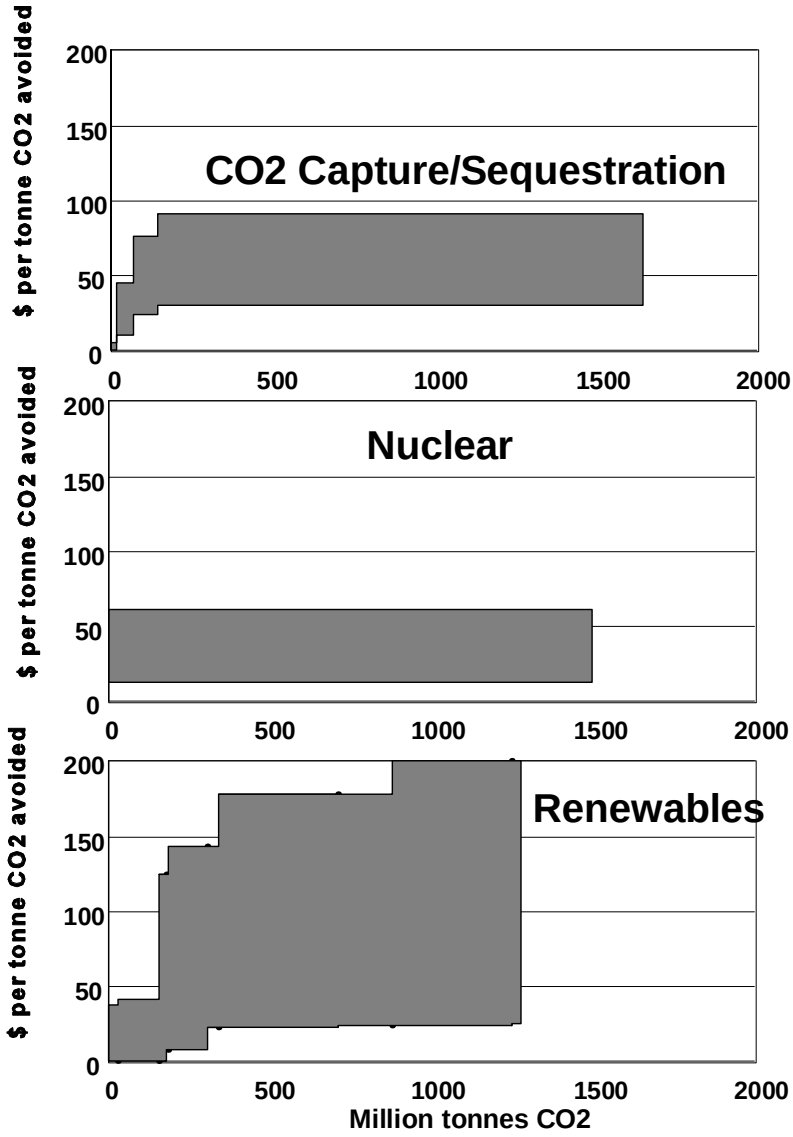


Figure 1. Comparison of US mitigation potential and cost (in 1990 $) of CO_2 capture and sequestration technologies with other leading mid- to long-term options.

Box 2. Conclusions of the 1993 DOE/MIT Research Needs Assessment

1. To implement CO_2 capture and sequestration on a national scale will decrease power plant net efficiencies and significantly increase the cost of electricity. To make responsible societal decisions, accurate and consistent economic and environmental analysis of all alternatives for atmospheric CO_2 mitigation are required.

2. Commercial CO_2 capture technology, though expensive and energy intensive, exists today.

3. The most promising approach to more economical CO_2 capture is to develop power plant systems that facilitate efficient CO_2 capture.

4. While CO_2 disposal in depleted oil and gas reservoirs is feasible today, the ability to dispose of large quantities of CO_2 is highly uncertain because of both technical and institutional issues. Disposal into the deep ocean or confined aquifers offers the potential for large quantity disposal, but there are technical, safety, liability, and environmental issues to resolve. Therefore, the highest priority research should focus on establishing the feasibility of large scale disposal options.

5. Land or ocean disposal will require research to better understand environmental impacts. Even with such information, the public may be reluctant to accept some disposal options.

6. While transportation of compressed, liquid CO_2 has been demonstrated, important issues involving cost, safety, liability, and institutional barriers to large scale deployment remain.

7. Individual options for using captured power plant CO_2 in an alternate fuel, as an industrial feedstock, or as an agricultural growth enhancer are not promising for sequestration of significant amounts of CO_2.

4. Capture Technology

The idea of capturing CO_2 from the flue gas of power plants did not start with concern about the greenhouse effect. Rather, it gained attention as a possible economic source of CO_2, especially for use in enhanced oil recovery (EOR) operations where CO_2 is injected into oil reservoirs to increase the mobility of the oil and, therefore, the productivity of the reservoir. Several commercial CO_2 capture plants were constructed in the late 1970s and early 1980s in the US (Arnold *et al.*, 1982; Hopson, 1985; Kaplan, 1982; Pauley *et al.*, 1984). The North American Chemical Plant in Trona, CA, which uses this process to produce CO_2 for carbonation of brine, started operation in 1978 and is still operating today. However, when the price of oil dropped in the mid-1980s, the recovered CO_2 was too expensive for EOR operations and all of the other CO_2 capture plants were closed. Several more CO_2 capture plants were subsequently built (Barchas and Davis, 1992; Sander and Mariz, 1992) to take advantage of some of the economic incentives in the Public Utility Regulatory Policies Act (PURPA) of 1978 for "qualifying facilities".

Historically, CO_2 capture processes have required significant amounts of energy, which reduces the power plant's net power output. For example, the output of a 500 MW_e (net) coal-fired power plant may be reduced to 400 MW_e (net) after CO_2 capture. This imposes an "energy penalty" of 20% (i.e., (500-400)/500). The energy penalty has a major effect on the overall costs (see Box 3). Table 2 shows typical energy penalties associated with CO_2 capture -- both as the technology exists today and how it is expected to evolve in the next 10-20 years. Both conventional coal and gas use similar capture technologies, but because gas is less carbon intensive than coal, it has a lower energy penalty. As will be discussed below, the relatively low energy penalty for advanced coal can be attributed to features in its process that allow for less energy intensive capture methods.

TABLE 2. Typical Energy Penalties due to CO_2 Capture

Power Plant Type	Today	Future
Conventional Coal	27 - 37% (Herzog and Drake, 1993)	15% (Mimura *et al.*, 1997)
Gas	15 - 24% (Herzog and Drake, 1993)	10 - 11% (Mimura *et al.*, 1997)
Advanced Coal	13 - 17% (Herzog and Drake, 1993)	9% (Herzog and Drake, 1993)

To reduce the energy requirements and bring the cost of CO_2 capture to acceptable levels will require a combination of the following:

- increased base power plant efficiencies. This once again highlights the importance of existing FE efficiency programs.

- reduced capture process energy needs.

- integration of the capture process with the power plant.

To date, all commercial CO_2 capture plants use processes based on chemical absorption with a monoethanolamine (MEA) solvent. MEA was developed over 60 years ago as a general, non-selective solvent to remove acid gases, such as CO_2 and H_2S, from natural gas streams. The process was modified to incorporate inhibitors to resist solvent degradation and equipment corrosion when applied to CO_2 capture from flue gas. Also, the solvent strength was kept relatively low, resulting in large equipment sizes and high regeneration energy requirements (Leci, 1997). As shown in Figure 2, the process allows flue gas to contact an MEA solution in the absorber. The MEA selectively absorbs the CO_2 and is then sent to a stripper. In the stripper, the CO_2-rich MEA solution is heated to release almost pure CO_2. The lean MEA solution is then recycled to the absorber.

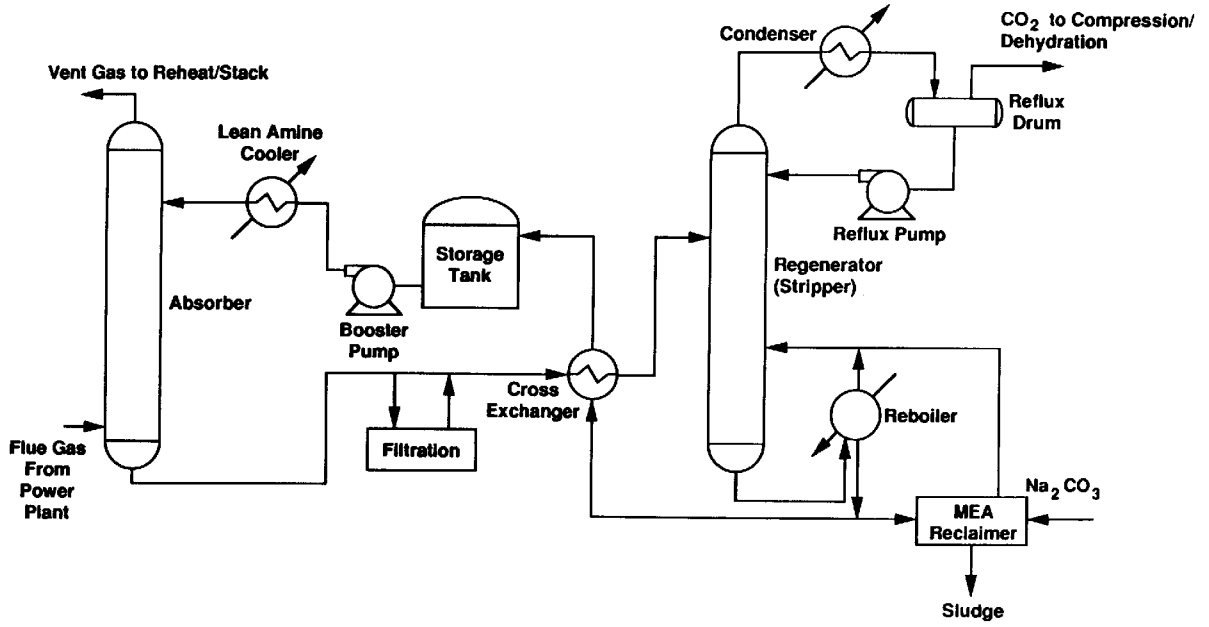


Figure 2. Process flow diagram for the amine separation process.

Other processes have been considered to capture the CO_2 from the flue gas of a power plant -- e.g., membrane separation, cryogenic fractionation, and adsorption using molecular sieves -- but they are even less energy efficient and more expensive than chemical absorption. The reason can be attributed to the very low CO_2 partial pressure in the flue gas. Therefore, a high priority research need is to formulate new solvents that can significantly reduce the energy penalty associated with chemical absorption. The most extensive research on improved solvents has taken place in Japan, including the Tokyo Electric Power Company and Hitachi (Arashi *et al.*, 1997) and the Kansai Electric Power Company (Mimura *et al.*, 1997). Pilot plant studies have shown that by developing new solvent technology and integrating the steam requirements for the CO_2 stripper with the power plant turbines, the energy penalty for CO_2 capture and compression can be lowered to 10-11% for gas and 15% for conventional coal (Mimura *et al.*, 1997).

Another way to reduce cost in chemical absorption systems is to reduce equipment size. By increasing the contacting efficiency between the CO_2 and the solvent, equipment sizes can be reduced significantly. Research at the University of Regina in Canada on structured packing indicates that absorber sizes can be reduced by a factor of five (Aroonwilas and Tontiwachwuthikul, 1997). Feron and Jansen (1997) of TNO Institute of Environmental and Energy Technology in the Netherlands have researched a membrane gas/liquid contactor and claim a three- to ten-fold reduction in equipment size.

An alternate approach to removing CO_2 from the flue gas is to use oxygen for combustion instead of air. To maintain thermal conditions in the combustion zone and prevent overheating of the furnace liner materials, some of the flue gas would be recycled to the furnace, giving this approach the name "CO_2 recycle technology". Since the key to scrubbing CO_2 from flue gas is to separate the CO_2 from the nitrogen, eliminating the air removes the primary source of nitrogen, greatly simplifying the flue gas clean-up. Of course, producing the oxygen now becomes a major expense. However, using oxygen instead of air opens up new possibilities for increased combustion efficiencies. Trace impurities would end up in the CO_2 effluent stream and might be suitable for disposition with the CO_2. Since mandated SO_2 and NO_x emission controls already add to the cost of producing electricity, these could be counted as credits toward the CO_2 control costs. This approach may be better suited for new plants (vs. retrofits of existing plants) because new plants can better take advantage of the improved efficiency opportunities related to oxygen use and because of questions concerning retrofits (e.g., air inleakage).

Advanced coal power plants offer many new opportunities for CO_2 capture. One example is to integrate CO_2 capture with an integrated gasification - combined cycle (IGCC) power plant (Doctor *et al.*, 1996). IGCC plants first gasify the fuel to produce a pressurized synthesis gas (mainly CO and H_2). Next, for CO_2 capture, after removal of impurities that might foul the catalyst, the synthesis gas is reacted with steam in a shift reactor to produce CO_2 and H_2. The CO_2 and H_2 are then separated, with the hydrogen being combusted to produce CO_2-free energy. The CO_2 stream is available for use or disposal. The partial pressure of CO_2 is sufficiently large in an IGCC plant (as opposed to pulverized coal plants) to allow use of a physical absorbent like Selexol (dimethyl ether of polyethylene glycol), which greatly reduces the energy requirements.

Currently, the biggest drawback to this approach is that IGCC power plants cost more than conventional pulverized coal-fired power plants. However, it is expected that costs of IGCC power plants will become competitive in the future.

Power technologies such as fuel cells or other advanced cycles are evolving and may become available to use the hydrogen rich fuel gas produced from the coal gasifier/shift-reactor/CO_2-separator. These technologies are likely to yield higher energy efficiencies and, therefore, further reduce the penalties associated with CO_2 capture.

In addition to power plants, there are a number of large CO_2-emitting industrial sources that could also be considered for application of capture and sequestration technologies. In natural gas operations, CO_2 is generated as a by-product. In general, gas fields contain up to 20% (by volume) CO_2, most of which must be removed to produce pipeline quality gas. Therefore, sequestration of CO_2 from natural gas operations is a logical first step in applying CO_2 capture technology, as witnessed by the Sleipner West project in Norway and the proposed Natuna project in Indonesia (see Chapter 3). Finally, in the future, similar opportunities for CO_2 sequestration may exist in the production of hydrogen-rich fuels (e.g., hydrogen or methanol) from carbon-rich feedstocks (e.g., natural gas, coal, or biomass). Specifically, such fuels could be used in low-temperature fuel cells for transport or for combined heat and power. Relatively pure CO_2 would result as a byproduct (Williams, 1996; Kaarstad and Audus, 1997).

There are several other industrial processes, primarily the production of ammonia and ethylene, which generate nearly pure CO_2 streams and therefore allow relatively inexpensive recovery of CO_2 -- with recovery costs per tonne of CO_2 avoided about half those of the best power plant recovery processes. Refineries, especially those that use heavier crudes, also provide some opportunities for CO_2 capture and have costs for capture per tonne of CO_2 avoided that are comparable to or somewhat greater than similar costs for capture from power plants. Other major CO_2-emitting industries, including iron and steel production and the broader petrochemical industries, have CO_2 capture costs per tonne avoided about twice those for capture from power plants (Farla *et al.*, 1992).

Summary. The key challenge regarding CO_2 capture technology is to reduce the overall cost by lowering both the energy and the capital cost requirements. While costs and energy requirements for today's capture processes are high, opportunities for significant reductions exist since researchers have only recently started to address these needs. The following approaches appear the most fruitful:

- Implement the easy opportunities first, such as those in the natural gas industry and industries like ammonia and ethylene.

- Improve today's commercially available chemical absorption processes. Key research needs are to develop more energy efficient solvents and reduce equipment size and cost.

- Use oxygen instead of air for combustion, producing a flue gas from which CO_2 is easily captured. Research needs include reducing oxygen costs, addressing the problems associated with retrofitting existing plants, and optimizing the efficiency of new plants.

- Integrate CO_2 capture into advanced power plants, such as IGCC or fuel cells. Research needs to address improved separation techniques (e.g., membranes), improved shift catalysts, and heat and power integration.

BOX 3. CALCULATING THE COST OF CAPTURE

The following example demonstrates a simple and straight forward method to estimate the cost of capturing CO_2 from a fossil fuel-fired power plant. While the example is presented to illustrate the methodology, we did attempt to use realistic numbers for our sample calculations.

Step 1: Calculate the cost of power without capture.

Basis: 500 MW_e pulverized coal-fired power plant (new construction) with a 65% annual capacity factor.

Calculation of generating cost:

	mills/kWh_e
Capital Cost ($1160/kW)	23.5
Fixed O&M ($14.5/kW/yr)	2.5
Variable O&M	2
Fuel	18
Generating Cost	46

In addition to the generating cost, the consumer must also pay for other costs (transmission and distribution, etc.). For this example, we fix these other costs at 2¢/kWh_e. These costs are be assumed to be unaffected by the implementation of CO_2 capture.

Generating Cost	4.6¢/kWh_e
Other Costs	2.0¢/kWh_e
Delivered Cost of Electricity	6.6¢/kWh_e

Step 2: Calculate cost of the CO_2 capture plant (excluding fuel). The fuel to drive the CO_2 capture plant comes from the power plant, so that cost was listed in Step 1. However, using this fuel for CO_2 capture derates the power plant, which will be accounted for in Step 3.

Basis: 90% capture efficiency (≈ 9000 tonnes of CO_2 captured/day) and a 20% energy penalty (reduces power plant net output from 500 MW_e to 400 MW_e). Captured CO_2 compressed above 100 bars.

	mills/kWh_e
Capital Cost ($270 million)	11
Fixed O&M	1.5
Variable O&M	1
Generating Cost	13.5

Step 3: Calculate cost of power with capture.

	mills/kWh_e
Base plant generating cost	46
CO_2 capture plant cost (excluding fuel)	13.5
Generating Cost	59.5

The cost of 59.5 mills/kWh_e is based on a net generation of 500 MW_e net. To account for the power plant derating:

$$\frac{59.5 \text{ mills}}{\text{kWh}_e \text{ (before capture)}} \times \frac{500 \text{ MW}_e \text{ (before capture)}}{400 \text{ MW}_e \text{ (after capture)}} = 74.4 \text{ mills/kWh}_e \text{ (after capture)}$$

Generating costs (with capture)	7.44 ¢/kWh_e
Other costs	2 ¢/kWh_e
Cost of electricity (with capture)	9.44 ¢/kWh_e

Increase in cost of electricity = 2.84¢/kWh_e (43% increase)

Step 4: Calculate the cost of capture to compare with other mitigation options.

		Base	Capture
Cost of electricity	6.6 ¢/kWh_e	9.44 ¢/kWh_e	
CO_2 emissions to atmosphere (kg/s)		115 kg/s	11.5 kg/s
Net output		500 MW_e	400 MW_e
CO_2 emissions (kg/kWh_e)		0.828 kg/kWh_e	0.104kg/kWh_e

$$\text{Cost of capture} = \frac{(9.44 - 6.6)¢/\text{kWh}_e}{(.828 - .104)\text{kg/kWh}_e} = 3.9¢/\text{kg} = \$39/\text{tonne } CO_2 \text{ avoided}$$

5. Geological Storage Technology

Underground storage in geological formations is a major option for disposing of CO_2. As described in Chapter 3, geological storage is currently being demonstrated: CO_2 from Norwegian gas fields is presently being stored in an undersea aquifer in the North Sea, and a substantially larger project may soon be undertaken by Exxon and Pertamina at their natural gas field at Natuna in the South China Sea. The main issues are uncertainties in the volumes available for storage (see Box 4), the long-term integrity of the storage, and the costs associated with CO_2 transport to the storage site and the storage operation itself (Herzog *et al*., 1993; Freund and Ormerod, 1997). Storage integrity is important not only to prevent the unintended return of CO_2 to the atmosphere, but also for concerns about public safety and the potential liability should there be a catastrophic release. CO_2 gas is heavier than air and, if a large release were to occur, it could displace air at the surface and cause asphyxiation.

The main options for underground storage are (Herzog *et al.*, 1993):

- storage in active oil reservoirs
- storage in coal beds
- storage in depleted oil and gas reservoirs
- storage in deep aquifers
- storage in mined salt domes or rock caverns

The relative merits of these options are described in Table 3 and include issues of storage capacity, cost, storage integrity and feasibility.

TABLE 3. Comparison of Geological Storage Options

Storage Option	Relative Capacity	Relative Cost	Storage Integrity	Technical Feasibility
Active oil wells (EOR)	Small	Very Low	Good	High
Coal beds	Unknown	Low	Unknown	Unknown
Depleted oil/gas wells	Moderate	Low	Good	High
Deep aquifers	Large	Unknown	Unknown	Unknown
Mined caverns/ salt domes	Large	Very High	Good	High

Depleted oil and gas reservoirs appear to be the most promising land storage option, at least in the near-term (Herzog *et al*., 1993). Because these reservoirs have already demonstrated their ability to contain pressurized fluids for long periods of time, their storage integrity is likely to be good. Currently abandoned oil and gas reservoirs in the US could hold about 2.9 billion tonnes of CO_2, while the ultimate reserves of oil and gas would hold roughly 100 billion tonnes of CO_2 (Winter and Bergman, 1996). These compare with current US power plant emissions of about 1.7 billion tonnes of CO_2 per year. However, most of the wells would have to be redrilled, and actual effective capacity is uncertain given that changes to the reservoir may have occurred due to water/brine intrusion or geostructural alteration. The oil and gas industry has significant experience in the management of such reservoirs, but is particularly concerned about long-term liability issues. With the exception of Texas, most oil and gas reservoirs are not located near primary sources of CO_2 production, so a new CO_2 pipeline network would be needed to connect power plants with suitable storage sites. The costs, environmental impacts and safety issues associated with such a network need to be considered in any analysis of this storage option. Due largely to differences in required pipelining, storage costs will be very site-specific. A cost study for several specific sites in Texas has been performed by Bergman *et al.* (1997).

Active oil and gas reservoirs could also be used. For example, CO_2 is used routinely for enhanced oil recovery (OTA, 1978; Lake, 1989). The amount of CO_2 that can be utilized for EOR and related applications is small compared to total CO_2 emissions and CO_2 can currently be supplied from natural sources at about one-third the cost projected for CO_2 captured from power plants (Herzog *et al.*, 1993). Hence there is no immediate incentive to utilize power plant CO_2 for this purpose. However, if credits for the avoided CO_2 emissions are considered, the price of power plant CO_2 is reduced and this option becomes very attractive. While the basic technology exists for EOR, additional research is required to modify EOR operations to optimize the storage of CO_2.

CO_2 can also be used to enhance the recovery of coal bed methane (Gunter *et al.,* 1997). Using this technology, abandoned and uneconomic coal seams become potential storage sites. Unlike EOR, where CO_2 break-through eventually occurs, the injected CO_2 becomes sorbed to the coal surface and hence remains sequestered. Estimated US coal bed methane resources are large -- ranging from 275 to 649 trillion cubic feet, with current production coming mainly from the San Juan Basin in SW Colorado and the Black Warrior basin in Alabama (Dawson, 1995). Although still in the development stage, the process has been tested in pilot scale field studies conducted by Amoco and Meridian in the San Juan Basin.

Mined salt domes or rock caverns theoretically have a large storage capacity, and have been used for the related purposes of storing petroleum, compressed air and natural gas (Tek, 1989), but the associated costs are a major impediment. Without a major breakthrough, the costs of excavating rock caverns are too high to be practical. Salt domes can be excavated at more reasonable cost by solution mining. However, in both cases large amounts of rock or brine would have to be excavated, handled and either utilized or disposed of in an environmentally acceptable manner.

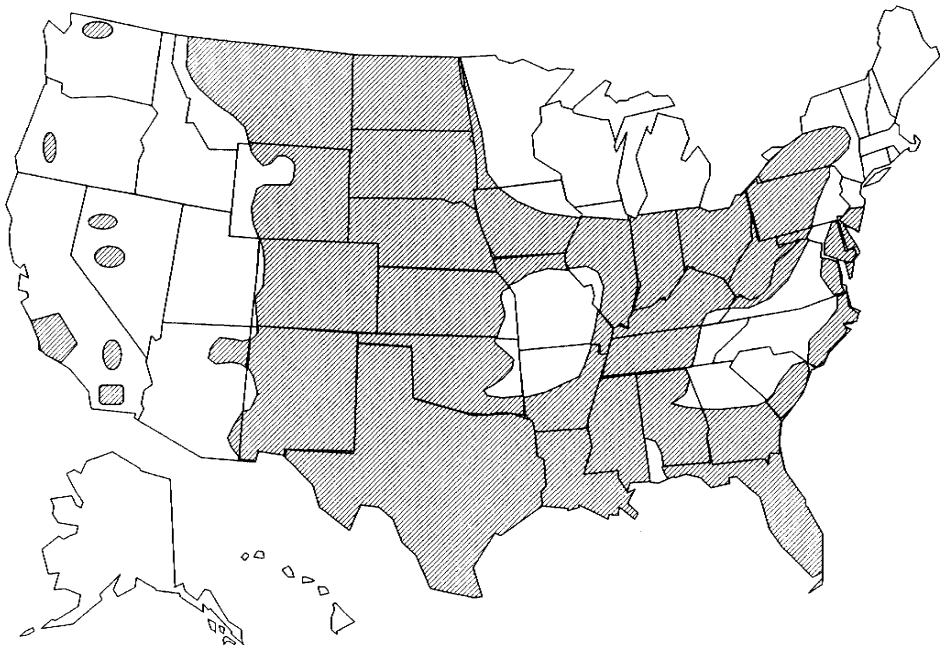


Figure 3. Saline aquifers in the US based on US geological survey (Bergman and Winter, 1996).

Deep aquifers may be the best long-term underground storage option. Such aquifers are generally saline and hydraulically separated from shallower aquifers and surface water supplies used for drinking water. Depending on the aquifer properties, injected CO_2 would displace water some of it remaining as pure CO_2 (Gunter *et al.*, 1993; Hitchon, 1996). The estimated storage potential of deep aquifers in the US is 5-500 billion tonnes of CO_2 (Bergman and Winter, 1996) compared with annual US power plant emissions of about 1.7 billion tonnes of CO_2. Figure 3 shows the locations of deep aquifers underlying the US. The spatial match between storage locations and CO_2 sources is somewhat better for deep aquifers than for gas and oil reservoirs; indeed, Bergman and Winter (1996) estimate that 65% of CO_2 captured from US power plants could possibly be injected directly into deep aquifers without the need for long pipelines. Because there has been less interest in them, the properties of aquifers are not as well known as those of oil and gas reservoirs, which leads to technical uncertainty. The aquifer should be located under a relatively impermeable cap, yet there should be high permeability, as well as porosity, below the cap to allow the CO_2 to be distributed efficiently. Effects of gravity segregation and fingering may

limit the effective storage, and fractures and open peripheries can allow leakage (Lindeberg, 1997). Issues of safety associated with leakage are also a major concern (Holloway, 1997). Energy companies have proprietary information that may help clarify some of these technological concerns and provide more accurate information on aquifer locations in the US, but issues of liability will have to be resolved before industry cooperation can be expected. Experience can also be gleaned from the disposal of industrial wastes as the US currently uses over 400 wells to inject about 75 million cubic meters of industrial waste (some hazardous; some non-hazardous) into deep aquifers each year (Bergman and Winter, 1996). However, regulations on aquifer disposal vary from state to state and not all states would currently allow such disposal. DOE/PETC has initiated a study of the economic, legal, environmental and social issues surrounding the use of the Mt. Simon Aquifer, a large aquifer which underlies Illinois, Indiana, Ohio, Michigan, Kentucky and Pennsylvania.

Costs for geological storage of CO_2 may vary from \$1-8 per tonne CO_2 depending on local circumstances. Transportation costs via pipeline have been estimated at \$1-3 per tonne CO_2 per 100 km (Hendriks, 1994). The range of costs for disposal (including transportation) used in the analysis in Chapter 3 was \$5-15 per tonne CO_2.

Based on the above discussion, several steps need to be implemented to further the development of land-based CO_2 storage. It should be emphasized that some of the needed information is actually available, but not accessible due to proprietary and anti-trust considerations; these obstacles must be overcome in order to avoid costly duplication. The needs include:

- Perform a quantitative assessment of storage volume at depleted gas and oil field sites in the US. The study should be national in scope and include input from the American Petroleum Institute, the American Gas Association and the National Petroleum Council.

- Assess the storage integrity characteristics of depleted fields and their suitability for re-opening to inject CO_2. Also, determine how best to "finish" currently producing wells for future CO_2 storage.

- Establish a methodology for assessing the long-term integrity and ecological impacts of storage, as well as the safety risk for underground reservoir types.

- Test modifications in EOR operations to maximize CO_2 sequestration as well as oil recovery.

- Continue testing the use of CO_2 to increase coal bed methane production and explore synergies whereby coal bed methane, produced with the enhancement of waste CO_2, could fuel power plants resulting in no net CO_2 emissions.

- Finally, because deep aquifer storage holds the best long-term promise, but is also the least certain, this option deserves special consideration:

- Conduct basic theoretical and laboratory research concerning the fluid, thermal and geological properties of deep aquifers in order to refine technical feasibility criteria.

- Conduct a comprehensive survey of industrial and government data on the location and nature of deep aquifers throughout the US (including off-shore aquifers) that meet the feasibility criteria. Much of the needed data does not exist and will need to be collected.

- Conduct an economic analysis of capital and operating costs for this option with specific attention to identified sites in the US.

- Conduct a domestic field demonstration project.

Box 4. Worldwide Storage Potential for CO_2

The IEA Greenhouse Gas R&D Programme estimated the worldwide storage potential in billion tonnes of CO_2 (Ormerod, 1994). As reflected in the large ranges below, this task is very difficult given all the uncertainties:

- Deep Ocean 5,100 - >100,000

- Deep Aquifers 320 - 10,000

- Depleted Gas Reservoirs 500 - 1100

- Depleted Oil Reservoirs 150 - 700

Since the world produces about 22 billion tonnes of CO_2 annually from energy production, it is clear that the theoretical capacities are more than adequate. Research is required to help narrow these ranges and determine what portion of this potential can be practically exploited.

6. Ocean Storage Technology

The ocean represents the largest potential sink for anthropogenic CO_2 (see Box 4) and it already contains the estimated equivalent of 140,000 billion tonnes of CO_2 (compared with annual worldwide anthropogenic emissions of about 22 billion tonnes of CO_2). Furthermore, discharging CO_2 directly to the ocean would accelerate the ongoing, but slow, natural processes by which over 90% of present-day emissions are currently entering the ocean *indirectly* (Sarmiento, 1993). As indicated schematically by Figure 4, discharging CO_2 directly to the ocean would reduce both peak atmospheric CO_2 concentrations and their rate of increase. However, CO_2 concentrations in the atmosphere and ocean will equilibrate over time scales of 1000 years or more, regardless of where the CO_2 is discharged. The ocean storage concept was first mentioned by Marchetti (1977) who conceived of piping CO_2 into the outflow of the Mediterranean Sea, where it would sink deeper into the Atlantic. Some follow-up work was undertaken in the late 1970s (e.g., Hoffert *et al.*, 1979; Baes *et al.*, 1980), but most research has taken place in the past six years, principally by researchers in Japan, Norway and the United States.

Figure 5 illustrates five methods for the direct injection of CO_2 into the ocean:

- dry ice released at the ocean surface from a ship (Nakashiki *et al.*, 1991).
- liquid CO_2 injected at a depth of about 1000 m from a pipe towed by a moving ship and forming a rising droplet plume (Ozaki *et al.*, 1995).
- liquid CO_2 injected at a depth of about 1000 m from a manifold lying on the ocean bottom and forming a rising droplet plume (Liro *et al.*, 1992).
- a dense CO_2-seawater mixture created at a depth of between 500 and 1000 m forming a sinking bottom gravity current (Haugan and Drange, 1992).
- liquid CO_2 introduced to a sea floor depression forming a stable "deep lake" at a depth of about 4000 m (Ohsumi, 1995).

The relative merits of each scenario involve issues of sequestration efficiency, cost and technical feasibility, and environmental impact (see Table 4).

Sequestration efficiency relates to how long the CO_2 will remain in the ocean before ultimately equilibrating with the atmosphere (Figure 4). As shown through the use of global circulation models, sequestration efficiency is clearly site-specific (Bacastow and Dewey, 1996). If the injected CO_2 can be incorporated in the general oceanic deep water circulation, a residence time of approximately 1000 years can be anticipated.

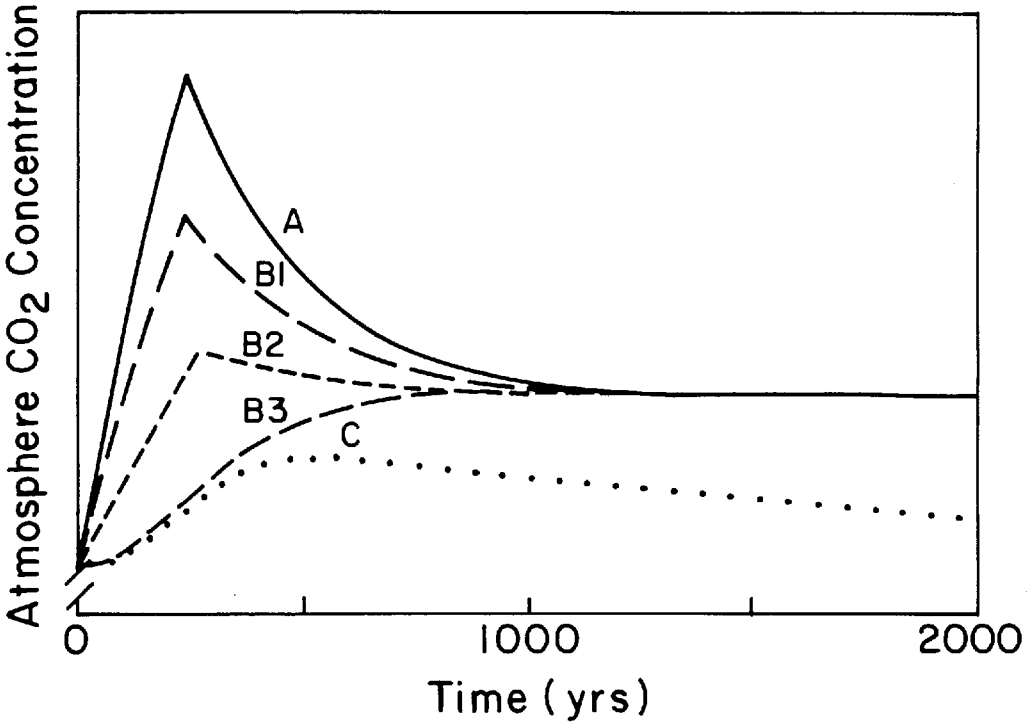


Figure 4. Qualitative illustration of the effect of ocean disposal on atmospheric CO_2 concentrations, based on a constant CO_2 emission rate for 250 years and then no further emissions. Line A represents business-as-usual emissions to the atmosphere. Because the atmosphere and ocean are out of equilibrium, atmospheric concentrations will decrease after emissions stop until an equilibrium is achieved at around 1000 years. Lines B1, B2, B3 show the effect of ocean storage with either increasing quantity of CO_2 injected to the ocean or increasing depth of disposal, leading to longer residence times. Line C shows the potential effect of carbonate chemistry (or solid deposition on the ocean floor) whereby some of the CO_2 becomes permanently sequestered, never to return to the atmosphere. (after Wilson, 1992.)

Costs and feasibility are functions of the distance and depths between CO_2 capture and injection. Shorter distances favor pipelines, with CO_2 compressed as a supercritical (dense phase) fluid, while longer distances favor barge transport as a refrigerated liquid (Golomb, 1997). In the case of dry ice, significant additional expenses would be incurred in solidifying the CO_2. Conventional pipe-laying technology has not been applied to depths much beyond 1000 m as would be required for a deep lake, though the reasons appear to reflect current needs of the oil and gas industry rather than any fundamental ocean engineering limitations (Palmer, 1997). Only scant experience with the technology for pipes towed from moving ships exists from OTEC research and incipient design work in Japan (Ozaki *et al.*, 1995; Ozaki, 1997). The dense gravity

TABLE 4. Comparison of Ocean Storage Options

Option	Development Required	Cost	Environmental Impact	Leakage to Atmosphere
Dry Ice	Lowest	High	Low	Low-Medium
Towed Pipe	Medium	Low-Medium	Lowest	Medium
Droplet Plume	Low	Low	Low-Medium	Medium
Dense Plume	Medium	Lowest	Highest	Medium
CO_2 Lake	Highest	High?	Low	Lowest

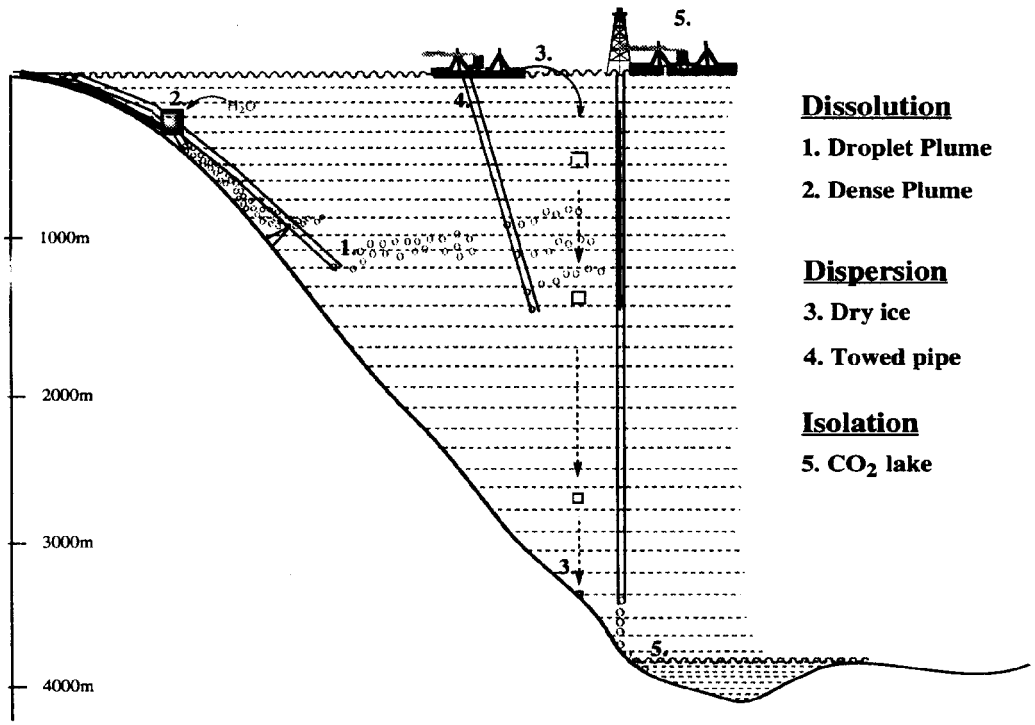


Figure 5. Five injection scenarios have been the focus of recent research. The scenarios are shown schematically above. A consensus is developing that the towed pipe and droplet plume scenarios offer the best approach for the near future.

current would require a suitable site with appropriate slope and design of a mixing device to concentrate the CO_2 (Adams *et al.*, 1995; Kajishima *et al.*, 1995) in order to generate sufficient negative buoyancy. Therefore, injection as a droplet plume from a bottom pipe is the only option which is feasible with proven technology, but even this option has uncertainties associated with the physical/chemical behavior of CO_2 as it mixes with seawater. Costs for ocean disposal of CO_2 (including transportation) have been estimated as low as \$1-6 per tonne CO_2 (Freund and Ormerod, 1997), but based on our work (Herzog *et al.*, 1995) we feel that \$5-15 per tonne CO_2 is a more realistic estimate.

Environmental impacts may be the most significant factor determining the acceptability of ocean storage, since the strategy is predicated on the notion that impacts to the ocean will be significantly less than the avoided impacts of continued emission to the atmosphere. Several reviews have identified potential impacts (Magnesen and Wahl, 1993; Kollek, 1993; Auerbach *et al.*, 1996), with the most significant deriving from lowered pH resulting from the reaction of CO_2 with seawater. Carbonate dissolved in seawater and in benthic sediments at shallow depths will provide a buffer, but depending on the method of release, pH can be expected to vary from as low as 4 very near the injection point, to its ambient value of about 8. Impacts would occur principally to non-swimming marine organisms (e.g., zooplankton, bacteria and benthos) residing at depths of about 1000 m or greater and their magnitude will depend on both the level of pH change and the duration of exposure (Auerbach, 1996). However, available data suggest that mortality associated with pH change can be completely avoided if the injection is properly designed to disperse the CO_2 as it dissolves (Caulfield, 1996).

At global scales, anthropogenic emissions of CO_2 that are occurring today will cause a gradual decline in average ocean pH of about 0.5 units over the next several centuries. Direct injection of CO_2 to the ocean will perturb the system by less than another 0.1 pH unit. However, the increased acidity due to the direct addition of CO_2 will occur primarily in the deep ocean, while acidification of the more productive surface waters would actually be mitigated (Haugan and Drange, 1995).

The viability of ocean storage as a greenhouse gas mitigation option will also hinge on social and political considerations. In view of public precaution toward the ocean, the strategy will require that all parties (private, public, non-governmental organizations) be included in ongoing research and debate.

Based on the above, we summarize the following research needs in the area of ocean storage:

- ***Physical-chemical interactions between CO_2 and seawater***, including the likelihood of hydrate formation on surfaces of CO_2 droplets contained in droplet plumes, and the interaction between CO_2-enriched seawater and stratified receiving water. Hydrates will affect mass transfer between CO_2 and seawater, and hence the elevation within the water column at which CO_2 is dissolved (Masutani *et al.*, 1995). Plume/ambient interaction will affect the elevation at which the CO_2-enriched seawater is ultimately sequestered and, in

particular, whether or not the plume will impact more environmentally sensitive benthic organisms.

- ***Ocean circulation and mixing.*** Mortality of marine organism in the near field (<25 km from the injection point) has been shown to be very sensitive to horizontal diffusivity (Caulfield, 1996), yet most available data are from near surface experiments. Better quantification of vertical mixing is also needed because such mixing helps control the residence time of CO_2 within the water column. To help in site selection and to better understand sequestration times, it is important to further the development, intercomparison, and field validation of three-dimensional circulation models for the far field (>300 km from the injection point), including better ways to couple regional and global scale models.

- ***Biological impacts.*** Environmental assessments to-date have been based on bioassays using surface organisms exposed to constant levels of pH. More tests are needed on organisms found at depths of order 1000 m, and with time-varying exposure. Also, data are required to evaluate chronic effects of existing and potential future trends in varying pH.

- ***Ocean engineering.*** The feasibility of laying deep CO_2 pipelines (greater than 1000 m), towing pipes from a moving ship, and creating a deep CO_2 lake has yet to be demonstrated. Such demonstration might allow discharge scenarios with less environmental impact and greater sequestration potential to be realized.

Many of these issues will require a combination of experimental and theoretical research. Laboratory research has progressed remarkably well over the last six years, especially in Japan (Ohsumi, 1995). However, many of the important physical, chemical and biological processes cannot be scaled, which means that more experimental research must eventually be conducted in the field. We believe this research should take place in three steps:

- small scale, short-term tests of physical/chemical perturbations conducted at an open ocean site. The US DOE is currently engaged in the planning of such an experiment -- a month-long field study conducted in collaboration with the Japanese at an open site such as the Kona coast of Hawaii.

- longer-term tests of acute and chronic biological impacts conducted at a semi-enclosed site such as a fjord.

- full scale testing using a prototype power plant outfitted for CO_2 capture.

Box 5. IEA Ocean Disposal Workshops

Between August 1995 and October 1996 the IEA Greenhouse Gas R&D Programme sponsored four workshops in which international experts convened to discuss the necessary steps toward demonstrating the feasibility of ocean disposal. The major conclusions of these workshops were:

Workshop 1 -- Ocean Circulation. Sequestration efficiency and large scale environmental impacts will depend on predictions from ocean global circulation models (OGCMs). To improve their reliability we must:

- involve the ocean modeling community more widely in the ocean storage concept.
- initiate an OGCM inter-comparison exercise on point sources of CO_2 in the deep ocean.
- support measurement programs which can provide validation data.

Workshop 2 -- Environmental Impacts. The concept of ocean storage requires that impacts to the marine environment be substantially less than avoided impacts of continued emissions to the atmosphere. To better quantify marine impacts we must:

- develop basic guidelines for biological acceptability.
- improve understanding of the physiological response of organisms through laboratory experiments under pressurized conditions and ultimately through *in situ* field experiments.
- collaborate with relevant existing marine biology research programs.
- research the impact of the business-as-usual scenario.

Workshop 3 -- International Links and Concerns. Global change is a worldwide problem requiring worldwide mitigation efforts and worldwide acceptance of these efforts. To facilitate this acceptance, we should:

- establish an international strategic advisory group consisting of science and technology experts, including representatives from other interest groups.
- involve other ongoing programs (e.g., International Geosphere-Biosphere Programme (IGBP), World Climate Research Programme (WCRP), IPCC).
- define processes for seeking legal and public acceptance.
- identify and involve stakeholders.
- learn from past examples.

Workshop 4 -- Practical and Experimental Approaches. In order to advance the concept of ocean disposal to the level of demonstrated technology, we must:

- develop experimental programs on biological impact (to gain understanding and acceptability) and near field plume behavior (to validate impact modeling).
- improve global/regional modeling to quantify benefits and identify sites.
- develop engineering solutions to refine injection options (sites, modes of discharge) and quantify costs and impacts.
- develop legal case and educate public.
- forge links with existing international science programs.

7. Direct Utilization Technologies

Recycling or reuse of CO_2 emitted or captured from power plants would seem to be an attractive alternative to the disposal options discussed in the two preceding chapters. However, the problem is finding enough uses to sequester a significant amount of the CO_2 generated. Today, the total industrial use of CO_2 in the US is about 40 million tonnes per year -- only about 2% of the 1.7 billion tonnes produced annually from our power plants. About 80% of this use is in enhanced oil recovery (EOR) and is supplied from CO_2 gas wells at prices much cheaper than power plant CO_2. Therefore, the challenge is to find new and larger uses that will consume the CO_2 or otherwise sequester it from the atmosphere. The candidate uses fall into three main categories: industrial uses, chemical conversion to fuels, and biological conversion to fuels.

Industrial uses. To illustrate the mismatch in quantities between power plant emissions and industrial use potential for CO_2, assume that CO_2 was substituted for fossil fuel feedstocks in all US plastics production. This total transformation of the US plastics industry to CO_2 feedstocks would require less than 100 million tonnes of CO_2 per year, about 5% of the 1.7 billion tonnes produced annually from US power plants. There are a number of other fairly small-scale industrial applications that could use captured CO_2 (Aresta and Tommasi, 1997). In a vigorous CO_2 mitigation effort, many small industrial activities could be converted to power plant CO_2 feedstreams, but the potential total impact would be much less than 1% of the total power plant CO_2 generated.

In a greenhouse gas-constrained world, it is likely that the industrial sector could reduce its own CO_2 emissions by identifying processes that produce relatively pure CO_2 streams and then either capturing and sequestering CO_2 or strategically linking it to another processing operation requiring CO_2 as a feedstock. There are numerous specific opportunities to reuse CO_2 in industrial processes, and certain processes such as ethylene and ammonia production produce high concentration CO_2 streams that are often currently released to the atmosphere. The standard way of producing hydrogen today is through steam reforming of methane which can be regulated to produce a CO_2/H_2 mixture which is easily separable.

$$CH_4 + 2H_2O = CO_2 + 4H_2 \qquad (7\text{-}1)$$

This CO_2 could be sequestered or utilized in another process. With increasing interest in the use of hydrogen as an energy carrier and fuel in the future, this CO_2 source is likely to grow and create an opportunity for additional mitigation. Even today, CO_2 from ammonia production is often used as a feedstock for urea production. Such streams would serve as a good feedstock for plastics production, production of inorganic carbonates, etc. Industrial combustion processes, like power plants, will have lower concentration streams of CO_2, making CO_2 capture more expensive as a way to mitigate emissions.

New applications might be found if further research is done on interesting potential reaction pathways. Since CO_2 is a very stable molecule, considerable energy is required to transform it into

products where the C-O bonds are broken, such as in recycling to fuels as discussed in the next section. Transformation into carbonates, carbamates, or other forms that retain or shift bonds is less energy intensive and the products also tend to be more stable. For example, a room temperature exothermic exchange reaction using CO_2 was recently reported on in *Chemical and Engineering News* ("Carbon Dioxide Fixation," p. 8, Nov. 11, 1996) for converting germanium or tin bisamides to industrially useful isocyanates and other products. However, in spite of the many diverse possibilities, the industrial sector still has only limited capacity for utilization of the large quantities of CO_2 that are generated by the power sector.

Carbonate minerals. Another possibility is to use CO_2 to make stable solid products like carbonate minerals that can be returned to the environment. This concept really could be considered as another form of geological storage. Weathering of alkaline rocks (especially calcium and magnesium silicates) is a natural method of CO_2 sequestration (Kojima *et al.*, 1997). To enhance the rate of the natural process, the authors suggest that olivine sand and wollastonite could be pulverized, dissolved, and reacted with power plant CO_2 to form magnesium and calcium carbonates. Energy needs for the pulverization generate CO_2 that is from 1 to 15% of the CO_2 sequestered. While the process seems feasible, large amounts of rock must be transported and handled -- several times the weight of the CO_2 sequestered -- as well as significant amounts of makeup hydrochloric acid. Lackner and Butt (1997) have done some preliminary calculations on this concept that suggest its potential for significant CO_2 mitigation at costs of about $30 per tonne of CO_2 sequestered (not including costs of capture) and they note that the scale of the operations would be somewhat smaller than the present scale of coal mining activities in the US. While further research is needed to support these preliminary estimates, this is an interesting possibility.

Dunsmore (1992) suggested the possibility of using underground brines rich in chlorine and sulfate, such as those in Canada's Elk Point salt basin, to produce carbonates. The brines could be pumped to a CO_2 contacter and the precipitate slurry could be reinjected. An *in situ* processing option also exists. Per tonne of CO_2 reacted, about 2.2 tonnes of precipitate would be formed. The residual brine would be highly acidic and about 0.5 tonnes of excess brine would be produced for reinjection or *in situ* reaction. The suitable brines are available in only a few locations and the environmental management of the acidic wastes presents a major problem. The quantities of solid materials that require handling, the large waste streams, and the transport distances to bring power plant CO_2 to the disposal site probably make this an impractical option for mitigation.

Chemical conversion to fuels. A large use that could begin to match power plant emissions of CO_2 is to "recycle" the CO_2 back to a fossil fuel that could reduce the use of virgin fossil fuels. Unfortunately, reducing CO_2 back to carbon requires at least 80% of the energy that is generated from burning a typical coal, and when processing losses are considered, there may be no net gain or even a loss of energy. Unless this energy comes from non-fossil sources, additional CO_2 is generated. And if non-fossil energy is available, in most cases it would be better used to substitute for the burning of coal in the first place.

Much interest has been generated in the possibility of converting CO_2 to a transportation fuel, such as methanol, using hydrogen.

$$CO_2 + 3H_2 = CH_3OH + H_2O \quad (7\text{-}2)$$

In this reaction, each molecule of CO_2 is reacted with three molecules of hydrogen to produce one molecule of methanol. But energy is required to produce hydrogen. The most efficient pathway to hydrogen today is through steam-methane reforming (see Eq. 7-1) which is about 80% efficient. Production from coal gasification is about 50% efficient; production from electrolysis of water, about 30% efficient (Rosen and Scott, 1996). In a simple example (Herzog *et al.*, 1993), it can be shown that about six units of solar (or other non-fossil) energy would be needed to recycle the CO_2 generated from producing one unit of energy in a coal-fired power plant, if the H_2 came from electrolysis of water. For that case, replacing the original coal energy by the non-fossil energy source is a much better solution from the standpoint of efficient energy utilization. If H_2 is available, the most energy efficient solutions will probably involve its direct use, such as in fuel cells, rather than as a reactant to recycle CO_2 to methanol.

Nevertheless, there is considerable research in progress, especially in Japan and Korea, on improved catalysts and catalytic pathways, both liquid and gas phase, to achieve high conversion and minimal energy loss in using H_2 to convert CO_2 to methanol. However efficient the conversion, the fundamental energy requirements to recycle CO_2 to methanol still make the conversion of very limited usefulness from an energy utilization viewpoint.

To produce as much methanol as possible per unit of CO_2, three molecules of methane are needed for each molecule of flue gas CO_2 and four molecules of methanol are then produced.

$$CO_2 + 3CH_4 + 2H_2O = 4CH_3OH \quad (7\text{-}3)$$

This means that only one molecule of CO_2 is being recycled and that three additional molecules of methane are being used and will emit additional CO_2 when the methanol is burned. Considering that the production of methanol is only about 60% efficient, it might be better to burn the natural gas in the power plant in the first place, or go to methane as an automotive fuel. This conclusion is similar to that of Audus and Oonk (1997) who conclude, based on a carbon-to-hydrogen ratio analysis, that producing methanol from CO_2 and H_2 (instead of by steam reforming of CH_4) is unlikely to make a significant contribution to a reduction in CO_2 emissions to the atmosphere (see Box 6).

An alternative route to producing hydrogen is by cracking the methane (Steinberg, 1996).

$$CH_4 = C + 2H_2 \quad (7\text{-}4)$$

With support from the Environmental Protection Agency, research on the thermal decomposition of methane is continuing. The residual carbon might be sequestered or used to replace current

uses for carbon black from virgin coal. The technologies involved are in early stages of development and it still is too early to see whether the efficiencies can be improved to the point where the process is feasible.

Biological conversion to fuels. Photosynthesis is the process by which plants, including algae, use solar energy to convert CO_2 to biomass. With about 500 billion tonnes per year of CO_2 fixed by terrestrial plants, the terrestrial biological carbon cycle is about twenty times larger than the production of CO_2 from fossil fuel combustion. Biomass is considered a renewable fuel because, upon burning, the CO_2 evolved matches the quantity of CO_2 recently removed from the atmosphere through the growth of the biomass. However, some additional energy may be needed to plant, fertilize, irrigate, harvest and process the biomass fuel crop. Biomass can be used to replace fossil fuels (e.g., combustion of wood fuels or agricultural residues) or can be processed to biofuels (e.g., gasifier gas, pyrolysis oils, ethanol, biodiesel, methane, hydrogen).

It was recently estimated that in the next century biomass fuels could mitigate 4 to 16 billion tonnes of CO_2 emissions annually (Sampson *et al.*, 1992). Most of these opportunities are indirect processes, independent of CO_2 production (see Chapter 9). Microalgae systems present the best biological technology for the direct capture and utilization of CO_2 emitted by power plants. The efficiency of conversion of solar energy to biomass is only around 1-3% for typical plant growth. However, there is much potential for improving the efficiency by up to an order of magnitude through the use of bioengineered species and low-cost/low-energy "biofarming" practices. Plant growth is thought to be enhanced by higher CO_2 concentrations, so some limited potential might exist for combining CO_2 rich streams captured from power plants with a greenhouse farming scheme.

Benemann (1997) has reviewed the possibilities in a recent paper that analyzes the different options and suggests fruitful areas for further research. Microalgae are of particular interest because of their rapid growth rates (up to ten times that of trees) and potential for significantly higher efficiency solar conversion than land plants. These microscopic plants would be grown in large open ponds, into which power plant flue gas or pure CO_2 (captured from power plants) is introduced as small bubbles. The estimated mitigation costs for this type of scheme would be up to $100 per tonne CO_2 recycled (with significant opportunities for further cost reduction); a pond area of about 50 - 100 square kilometers would be needed for a 500 MW_e power plant (Benneman and Oswald, 1996). After harvesting, the biomass would be converted to a fossil fuel replacement, preferably a high value liquid fuel such as biodiesel. Microalgae systems require a combination of land, water, and climate resources seldom found in conjunction with power plants. These factors currently constrain the likely reductions by microalgae systems in the US to a few tens of millions of tonnes of CO_2 per year -- perhaps 1% of present fossil CO_2 emissions. Again, this could be one element of a diverse set of utilization options that contribute to mitigation.

Until recently, there has not been much R&D effort on microalgal CO_2 utilization/recycling systems. There are some interesting possibilities when such systems are integrated in a synergistic manner with wastewater treatment systems. Work in Japan is concentrating on photobioreactors (Usui and Ikenouchi, 1997) and on new strains of microalgae and growing conditions. Work at the US National Renewable Energy Laboratory (Kadam, 1997) concludes that, although the costs are likely in the mid-term to be about $100 per tonne CO_2 recycled, the ponds would produce a lipid feedstock that could be used for biodiesel production at costs similar to the current crude soybean oil prices.

Summary. Although utilization does not seem to offer large scale opportunities for mitigation, it is important to recognize that a large number of small uses can play an important part of an overall mitigation strategy. Further, if CO_2 can be used as a feedstock for useful products, it provides a credit against capture costs and avoids incurring land or ocean storage costs. An overview of the status of utilization opportunities at present is:

- Many diverse industrial niche opportunities exist for use of power plant CO_2, for linking of industrial processes to minimize CO_2 emissions, or for inexpensive capture of CO_2-rich streams.

- Increased production of hydrogen for use as a fuel offers additional inexpensive CO_2 capture opportunities.

- Microalgae conversion of CO_2 to biomass is the leading candidate for direct biological utilization of power plant CO_2 and has potential for significant improvements in conversion productivity.

- Longer term prospects for potential storage of power plant CO_2 as minerals are interesting but uncertain as to practicality.

- Large-scale conversion of power plant CO_2 to fuels, such as methanol, appears unattractive based on the criteria of effective energy utilization.

Box 6. Suggested Feasibility Criteria for Evaluating Utilization Options

Audus and Oonk (1997) present the following criteria for evaluating the usefulness of potential utilization processes for significant CO_2 mitigation:

1. A reduction in net emissions of CO_2: Does the process consume carbon? (i.e., is the molar C/H ratio of the stable products greater than that of the raw materials?)

2. A reasonable energy input for conversion: The heat of reaction for the process should not be more than 1.25 times the heat of combustion of the reference fuel. (This rule of thumb gives good agreement for chemicals which are predominately carbon and hydrogen; but may give conflicting results with other chemicals).

3. When alternate utilization processes are being compared, the better choice will usually involve:
   - A reduction in the number of processing steps
   - Milder operating conditions
   - Fewer discontinuities in operating conditions
   - Improved possibilities for process integration

4. Favorable reaction equilibrium chemistry: Negative or slightly positive free energy change (ΔG) indicates that the equilibrium for the reaction favors the desired product.

5. Effectiveness:

   - Significant storage lifetime (time scales of 100 to 1000 years or more)
   - Market size sufficient to sequester at least 10 million tonnes CO_2 per year
   - Availability of co-reagents to process at least 10 million tonnes CO_2 per year

Two examples of applying these criteria are presented in their paper, with the following conclusions:

   - Fixation of CO_2 in inorganic carbonates seems a feasible method of reducing CO_2 emissions to the atmosphere.

   - In terms of reducing CO_2 emissions, producing methanol from steam reforming of methane is a better process route than production of methanol from CO_2 and H_2.

8. System Implementation Issues

The preceding chapters have looked at technologies for capturing CO_2 from fossil fuel-fired power plants and for sequestration by geological storage, ocean storage, and utilization. This chapter will discuss the potential integration of these technologies and the barriers and opportunities related to their implementation. There appears to be no single solution to the sequestration issue in the event that a major CO_2 mitigation program is implemented. Therefore, CO_2 mitigation will require a systems approach that must be integrated on a still higher level with other CO_2 mitigation options such as improved efficiency, increasing use of non-fossil fuels, and indirect means of atmospheric CO_2 reduction (see Chapter 9). Within the fossil fuel sector, energy efficiency improvements are usually double winners, both from the economic viewpoint of reduced fuel costs and from the reduction in CO_2 emissions, which also reduces the costs of capture and sequestration.

However, in developing additional strategies for selecting the most effective national portfolio of power plant CO_2 capture and sequestration systems, there are a number of important factors:

- ***Full cost analysis.*** For each major power plant (or industrial) source, the system costs include the costs of capture or reuse of the CO_2, costs of transportation to a storage or reuse point, the costs associated with the storage or reuse, and the costs associated with losses and inefficiencies. Such studies provide a rational basis for assessing tradeoffs between local environmental impacts and global impacts.

- ***Externality analysis.*** Full fuel cycle analysis requires the inclusion of external environmental and societal costs that are often neglected in traditional cost analyses. DOE and the Commission of the European Communities (CEC) have looked at externality valuation for fossil and non-fossil technologies (ORNL, 1994). The DOE and the IEA Greenhouse Gas R&D Programme have also attempted to evaluate the external costs of greenhouse gas emissions (Saroff, 1996; Audus, 1996).

- ***Sequestration effectiveness.*** Different modes of sequestration remove CO_2 from the atmosphere for different periods of time. Looking at possible future use of fossil fuels over periods of several hundred years, geologic storage appears relatively permanent. Ocean storage may be effective over time scales up to 1000 years or longer but is dependent on injection technologies and other factors.

- ***Uncertainty analysis.*** It is evident that sequestration methods vary considerably in the amount of uncertainty associated with their likely costs and effectiveness. Areas of large potential, but large uncertainty, are prime candidates for active research programs that are designed to identify key factors that will help in future strategy development and in the targeting of the most promising future research and development efforts.

- ***Legal and regulatory analysis.*** From global agreements that may drive national initiatives, to potential opportunities for actions implemented jointly by multilateral agreements, to issues of local and state regulations and jurisdiction, to laws of the sea, and other issues such as interstate transportation, a good understanding of the legal frameworks that may facilitate or impede implementation of desirable CO_2 mitigation technologies or policies is very important

- ***Public participation and education.*** At present, the US public is not very aware of the issues associated with global climate change and even less aware of the technological options for CO_2 capture and sequestration. These involve a range of environmental, land use, economic and societal impacts that will require the support of knowledgeable citizens and their political representatives. As the program evolves, clear dissemination of information, opportunities for interaction among diverse experts at workshops, workshop reports, and other opportunities for inputs and feedback will be important for the acceptability of alternative options.

One of the major challenges associated with full cost pathway analyses or externality analyses is to identify least cost and impact opportunities, which will vary on a site by site basis depending on the nature of the CO_2 source and distances from storage or use locations that appear to be suitable.

Regional issues. The choice of a CO_2 sequestration technology is likely to be dependent on siting because of transportation costs. Power plants are distributed throughout the US, with major concentrations near large population and industrial centers. Largest concentrations are in the northeast area in a band stretching from New York through Missouri. Other concentrated locations are in the southeast and in Texas (see Box 7).

Ocean storage will favor coastal locations that are near a suitable disposal site. For the US, offshore distances to reach 1000 m depths vary considerably. Subsea pipeline costs are expected to be in the order of $2 million or more per mile. While some general studies have commented on potential ocean storage sites for the US, no definitive study on specific CO_2 ocean disposal sites exist. A definitive study must investigate proximity of disposal sites to the power plant, transportation considerations, the ultimate fate of the injected CO_2, environmental considerations, and costs.

Storage in depleted oil and gas wells is another option, but US wells are of limited capacity and are mostly located in Texas and a couple of neighboring states (Winter and Bergman, 1996). These authors estimate that existing abandoned reservoirs could hold a total of about 2.9 billion tonnes of CO_2 (US power plants generate about 1.7 billion tonnes annually). Because wells are owned privately and are often abandoned with significant residual inventory due to economic reasons, it is difficult to inventory the true capacity. An estimate of total volume available from depletion of *all* US oil and gas reserves is 100 billion tonnes of CO_2. For power plants in Texas, the potential for disposal of significant quantities of CO_2 in depleted oil and gas wells appears

attractive. Pipelines would be required as part of the system, and with pipeline costs in rural areas at about $750,000 per mile, there are strong incentives to minimize transport distance. In more congested areas pipeline costs increase to around $1 million per mile or more. Pipeline distances from these mid-US power plant locations to suitable ocean disposal sites would be much greater and costs would likely be prohibitive.

The EPA already allows disposal of liquid industrial wastes into aquifers if a retention time of greater than 10,000 years can be proven. However, regulations on aquifer disposal vary from state to state and not all states would currently allow such disposal. Aquifers underlie large portions of the US -- about 65% of the US power plant CO_2 emissions are produced in these areas. Bergman and Winter (1996) estimate potential capacities of 5-500 billion tonnes of CO_2. This broad range reflects the uncertainties in the estimates! Further, very little is known about the behavior of CO_2 if it were injected into an aquifer. The CO_2 has different properties than the brine that is present in such aquifers and how it interacts and reacts with the brine and with various rock matrices is only a subject of conjecture at the present time.

Other storage and utilization options will also be geographically distributed and the best matches with CO_2 emission sources will require analysis on a system level that includes capture, transportation, and sequestration.

Barriers and Opportunities to Implementation. In the short-term (next 10 years), there are several significant barriers to implementing CO_2 capture and disposal technologies. The cost of capture is significant and must be reduced. Availability of viable utilization or storage options is also lacking. Finally, practical considerations regarding the ability to retrofit or repower existing power plants (e.g., is there enough land to add a capture plant?) need to be considered.

However, if one takes a medium-term (10-30 years) view, the opportunities for implementing CO_2 capture and sequestration technologies are much more positive. Research seems promising to significantly reduce the cost of capture. New power plants can more efficiently integrate CO_2 capture and sequestration technologies. Also, new power plants can be sited with CO_2 sequestration as a criteria, taking into account the transportation costs of both electricity and CO_2. In other words, CO_2 capture and sequestration technologies will allow one to build new fossil fuel power plants without generating significant greenhouse gases.

Environmental impacts of sequestration alternatives will need further elucidation, particularly for sequestration in aquifers and the oceans. Public education and involvement will be important in future decisions involving land use issues and environmental and social tradeoffs among alternatives.

From the above discussion, we conclude the following:

- In the short-term (up to 10 years), CO_2 capture and sequestration technologies will be viable only in niche applications, such as oil and gas operations (e.g., Sleipner West, Natuna), or fulfilling a commercial need for CO_2 (e.g., EOR).

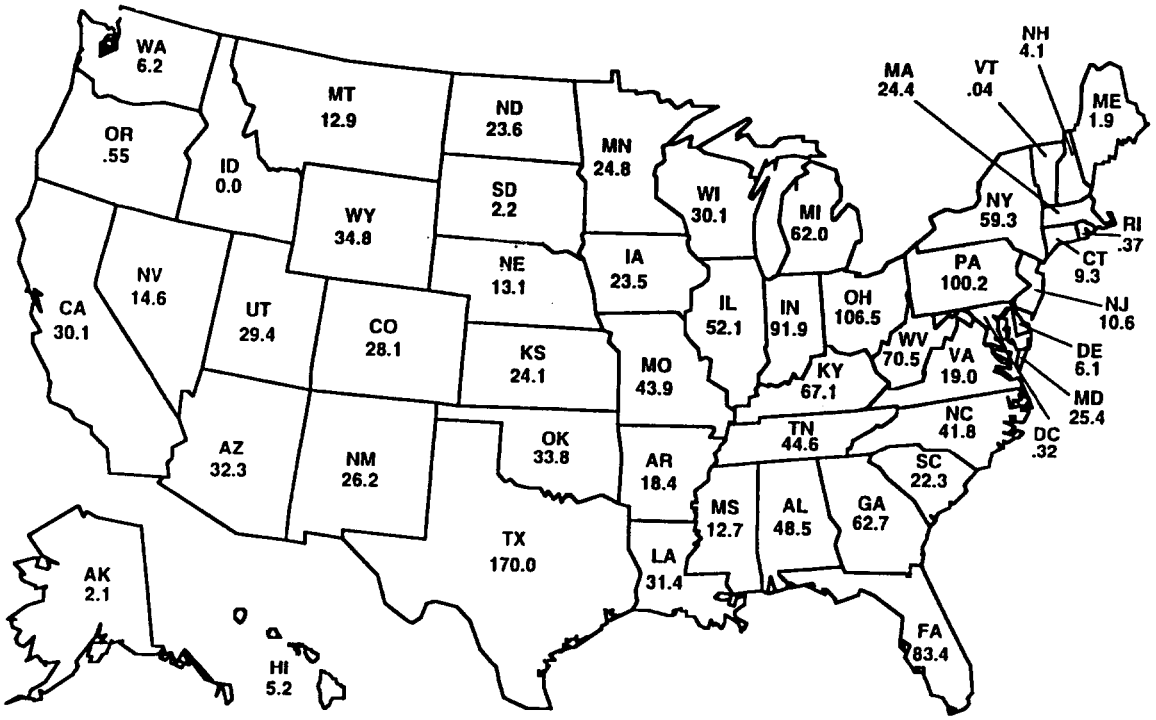
- In the medium-term (10-30 years), CO_2 capture and disposal technologies can be used to retrofit existing plants that have good alternatives for CO_2 disposal or use. In addition, new plants can be designed and sited to take advantage of integrated CO_2 capture and disposal opportunities.

- In the longer-term (30 years plus), we may see most new power plants include CO_2 control technology, just as today's power plant designs include technology to address the issues of SO_2, NO_x, and particulate control. If one of the broader energy strategies involves large scale use of hydrogen produced from natural gas, this technology also offers opportunity for inexpensive CO_2 capture and integration into sequestration systems.

Box 7. CO_2 PRODUCTION FROM US POWER PLANTS (1990)

(in millions of metric tonnes)

(Herzog *et al.*, 1993)



TOTAL = 1689

9. Other Approaches to CO_2 Reduction

As a short-term mitigation strategy, the US DOE is vigorously pursuing energy efficient technology development. This report has so far focused on technologies for CO_2 capture and sequestration for the mid- to longer-term. Additionally, there are a variety of other possibilities that may be of interest to the fossil fuel industry if they seek technologies for CO_2 swaps or offsets. As such, these programs would be of interest to others, including the US DOE Offices of Fossil Energy, Energy Research, and Energy Efficiency, plus other governmental agencies as they develop programs to meet mid- to longer-term mitigation goals.

Forestation. Trees and woody plants sequester CO_2 during their growth periods. Destruction of forests, especially with burning of residues, releases stored CO_2 back into the atmosphere. The forestation options include prevention of deforestation, afforestation (converting land back to forest), and reforestation (planting to create a new forest). During the life of a typical forest, biomass productivity is about 3-10 dry tonnes per hectare per year (about equivalent to fixing the same weight of CO_2) . As the forest matures over 100 years or so, some of the sequestered CO_2 can be released back to the atmosphere through decay of fallen trees or through forest fires. Once the forest is mature, additional carbon uptake is minimal. Planting costs are in the range of $1000 - $2000 per hectare in accessible areas (Yokoyama, 1997). If an area of 370 million hectares were reforested (about one half the size of the Amazon basin), about 3.6 billion tonnes of CO_2 could be captured annually until the forest matures (Jarvis, 1989). If no other costs are required for land acquisition, soil remediation, or irrigation, this provides initial CO_2 mitigation at a cost of $1 to 2 per tonne captured. The IPCC (Bruce *et al.*, 1996) estimates afforestation costs in the range of $3 - $10 per tonne of CO_2 sequestered, but notes that costs rise with the scale of activity. Real costs might be substantially higher if land costs and forest management are included, and if allowance is made for release of some of the CO_2 back to the atmosphere. Audus and Saroff (1995) present a full life cycle evaluation of an afforestation option in a temperate European country and estimate costs of around $26 per tonne of CO_2 avoided.

Several arguments beyond cost can be raised against major reforestation schemes. CO_2 sequestration into forests is limited and would diminish over the next century when needs for CO_2 mitigation are likely to be even more acute. The long-term fate of carbon sequestered in forests is somewhat uncertain as some ends up sequestered in the soil and some eventually returns to the atmosphere as CO_2. Carbon balances for various types of biomass are not well known. Also, widespread reforestation removes land from economic utility and requires that the mature forest not be utilized in the future in a manner that fosters release of the sequestered CO_2 to the atmosphere. However, reforestation of low productivity land may be useful, as is use of planting trees for shade and shelterbelts around buildings as an energy conservation measure. Also, reforestation might offer recreational benefits, could aid biodiversity if this were a parallel goal, and might be designed for protection of watersheds. It may also serve as a stepping stone towards more active sustainable utilization of the wood as biofuel for fossil fuel replacement or cofiring.

Bioenergy farming. A more active and sustainable approach to reforestation is the farming of biomass for a fossil fuel replacement. If trees or plants can be used as a fuel that displaces fossil fuel use, then a net reduction in CO_2 emissions occurs. Yokoyama (1997) indicates that the potential reforestation area available worldwide (for land that does not require major investments in soil improvement or irrigation) is about 340 million hectares. If all this land were developed for energy plantations, he computes a theoretical potential for mitigating 5.1 billion tonnes of CO_2 per year using Eucalyptus trees with a six year rotation. For comparison, the total area of Brazil is 850 million hectares. However, biomass energy involves additional costs in farm management, harvesting, and transportation. If transportation distances exceed 50 - 75 km, transportation energy becomes a significant portion of the energy gathered in the biomass. The best applications for biomass energy farming appear to be in smaller growing areas serving a medium size power plant or for use as a cofiring fuel with coal.

Utilization of biomass fuels. Biofuels presently make up about 4% of the primary energy used in the US and are used primarily in the forest products industries. Available forestry and agricultural wastes and residues could supply about twice this energy, if there were incentives for utilization (Robertson and Shapouri, 1993). Municipal solid waste generates about 2,000 MW_e in the US today. However, the wood power industry is in trouble, with plants in California and the Northeast being shut down for economic reasons, mainly from continuing falling fossil fuel and electricity prices, potentially worsened further by the deregulation of the electric power industry.

The efficient utilization of biomass in replacing fossil fuels should be a major part of any broad CO_2 mitigation program. To make biomass a more attractive fuel, technology improvements in combustion efficiency are needed. Currently, stand-alone biomass power plants have efficiencies of about 20-25% (on a higher heating value basis) compared to fossil fuels, which are typically used with 30-40% efficiencies. Thermochemical gasification may have potential for achieving improved efficiencies, but still requires considerable development to overcome problems with tar and alkali deposition, as well as with hot gas cleanup. Improved technologies are also being developed to allow the drying and combustion of entire trees, and for better handling of ash and slag in combustion chambers (Wiltsee *et al.*, 1993). Investment in improved biomass combustion technologies may serve as a bridge to more widespread use of biomass energy in the future.

The potential for producing liquid fuels from biomass is more limited. Starch or oil crops, used for conversion to ethanol or biodiesel, are expensive, energy intensive, and produce only moderate (or sometimes negative) CO_2 mitigation. While there may be niche uses because of the desirability of liquid fuels, the greatest potential for reducing fossil CO_2 emissions comes from use of solid biomass in cofiring or stand-alone power plants.

Cofiring biomass with coal and other fossil fuels. This option, which utilizes biofuel in a higher efficiency fossil fuel power plant, has been studied for many years (McGowin and Hughes, 1992). Earlier work emphasized cofiring of “refuse-derived fuels” (RDF), while more recent emphasis has shifted to wood-based fuels which are cleaner and more uniform than RDF. Cofiring of coal with wood wastes at low levels (about 1% by heat rate) is already in commercial practice at

several utility sites. Recently several utilities (Hunt *et al.*, 1997; Benjamin, 1997) have been testing cofiring of biomass fuels with coal at higher levels. Preliminary indications are that some types of existing boilers are suitable for burning biomass up to at least 10% of the heating rate and 20% of the weight of the feed. The biomass component reduces sulfur emissions and burner improvements may also lead to lower NO_x emissions; however, efficiency is reduced by the energy needed to pulverize the biomass and for vaporizing associated moisture. Active drying of biomass has a large energy penalty. Some thought is being given to burning biomass from selected dry waste streams, such as the sawdust from a sawmill.

Despite uncertainties, results from these studies suggest that for cyclone burners and for small-size biomass fuel, capital costs for the fuel preparation and feeding systems are only $100-200 per kW_e. Even for pulverized coal boilers, requiring more feed preparation and potential boiler modifications, costs appear substantially lower than any other end-of-pipe CO_2 mitigation option. However, a number of technical uncertainties remain to be resolved in cofiring: fly ash quality, maximum percentage of biomass that can be handled, and effects of resource variability in quality, cost and moisture content on overall plant performance. In September 1996, the DOE and the Electric Power Research Institute (EPRI) signed a $5 million, three-year cooperative agreement to co-fund cofiring and other CO_2 mitigation projects in collaboration with the electric utility industry (see Box 8).

Although a more detailed resource and economic analysis is required, preliminary estimates suggest that up to 5% of US coal-fired power plant emissions could be mitigated through co-firing, at a cost of less that $10 per tonne of CO_2 avoided (Hughes and Benneman, 1997). In the future, biomass suitable for cofiring could be greatly expanded by the use of specifically and intensively produced local wood fuels and energy crops.

Artificial photosynthesis. There has been on-going basic research to develop photochemical processes that mimic biological photosynthesis -- converting solar energy into fixed chemical energy, using chlorophyll as a catalyst. Most of these studies have focused on a photolysis process, producing hydrogen from water using sunlight. Although some ruthenium complexes were able to catalyze such a reaction, the low efficiencies and instability of the reaction are discouraging. This remains an interesting area for basic research, but possible success appears to lie far in the future (Lewis, 1995).

Hydrogen production by biophotolysis. Some very early studies (Miura *et al.*, 1997; Ohtaguchi *et al.*, 1997) are exploring bacterial systems that absorb CO_2 by light induced photosynthesis and then are subjected to a subsequent anaerobic fermentation step without light to generate H_2. An additional bioreactor can be used to convert the residual organic compounds to various biofuels. These novel systems create interesting possibilities, although they will be subject to the same types of scale-up constraints and costs that limit single-step bioconversion to fuels.

Another possibility is the use of certain algal strains which can split water to hydrogen and oxygen with a single light reaction. These algae can be grown with CO_2 as the sole carbon source

(Greenbaum, 1996). These types of reactions are very interesting, but will require much additional research and refinement for future usefulness.

Ocean fertilization to induce CO_2 fixation. Martin (1990) suggested that the scarcity of phytoplankton productivity in the Southern Ocean was due to limited concentrations of iron. Kumar *et al.* (1995) confirmed this hypothesis by showing that during glacial periods where iron-bearing dust fertilized the oceans, productivity was greatly enhanced. An experiment with iron dusting in the equatorial Pacific yielded a large increase in productivity that exceeded expectations and seemed to be sustained over a period of days (Dopyera, 1996). While the short-term uptake of CO_2 was evident, the experiment was too short to study the needs for continuing fertilization or of the net CO_2 sequestration over the life cycle of the phytoplankton. Uncertainties exist about where the phytoplankton release their carbonaceous material. Little net sequestration occurs if this is in the upper layers of the ocean rather than in the deep ocean. Other research in Japan (Horiuchi *et al.,* 1997) is exploring general ocean fertilization with nitrogen and phosphorus using activated sludge. Again, this appears to produce a net short-term assimilation of CO_2 by phytoplankton.

The next phase for this research will involve shipboard experiments in the Southern Ocean. The Southern Ocean is protected by a set of international laws designed specifically to keep the environment uncontaminated. More impact data will be needed to demonstrate that a future, larger scale Southern Ocean experiment is acceptable. However, until more is learned about the possible ecological impacts of iron fertilization, it should be considered a highly speculative longer-term CO_2 abatement option.

Offsetting the greenhouse effect. There are some more unlikely options that focus on inducing cooling to offset any global warming. It is known that sulfur emissions can produce aerosols that induce cooling in the atmosphere; this is usually not considered a responsible mitigation strategy (Messner, 1996). Proposals to "dust" the atmosphere (as is done naturally through major volcanic eruptions) also are a potential way of producing some cooling, as are proposals to orbit giant sunshades and the like. These geoengineering options seem extreme enough that they might only be seriously considered in the event of an impending global catastrophe.

Summary. In the short-term, afforestation/reforestation and co-firing of biomass and suitable waste products seem to offer considerable potential for CO_2 reduction. In the longer term, larger-scale biomass farming and dedicated biomass power plants may be feasible if efficiencies and residue handling problems can be solved. A continued research activity on the fundamental chemistry and biochemistry of CO_2 reactions may lead to still other possibilities that are promising, including direct bioproduction of hydrogen from CO_2.

Box 8. The DOE-PETC/EPRI Cooperative RD&D Agreement Planned Biomass Cofiring Projects (September 1996)

TVA	The Tennessee Valley Authority will continue precommercial extended test runs, leading to full-scale tests at TVA power plants with low and moderate levels of cofiring. Both 200 MW_e cyclone and wall-fired pulverized coal units are being investigated.
NYSEG	New York State Electric and Gas Company is conducting tests on the preparation of wood fuel for cofiring in a tangentially-fired pulverized coal unit, using a separate feed for the wood. Mid-level (10% of the thermal input) feeding rates will be used in a 100 MW_e boiler. Cofiring of short-rotation willow biomass crops is planned for early 1997.
GPU	General Public Utilities and EPRI will co-fund a mid-level cofiring test in a wall-fired 30 MW_e pulverized coal unit with a separate wood feed. Earlier work fed the wood through the pulverizers along with the coal, but this led to plant derating.
Southern Company	Southern Company has carried out short-term tests in a tangentially-fired pulverized coal boiler in Savannah GA, which indicates that separate wood feeding of up to 40% of the heating rate is possible. Longer term testing, possibly with some natural gas overfire, will allow exploration of the upper limits of cofiring.
Madison Gas and Electric	Madison Gas and Electric are conducting tests at a plant which had been previously retrofitted to burn refuse-derived fuel and shredded paper waste in a wall-fired 50 MW_e pulverized coal unit. The unit will be used to conduct the first US tests of cofiring switch grass (a proposed energy crop) with coal in a full-size utility boiler.
NIPSCO	Northern Indiana Public Service Company is completing a study evaluating fuel supply and power plant operation for cofiring wood in a full-size 500 MW_e cyclone burner at 5% of the thermal input.
University of Pittsburgh	The University of Pittsburgh is planning test burns in one or more of a series of chain grate stoker boilers (15 MW_e total), cofiring wood waste at up to 10% of the thermal input to the boilers. Urban wood residues will be used in these tests.

Projects on aquifer storage of CO_2 and the use of microalgae for wastewater treatment are also contained in this agreement.

10. Proposed Plans and Actions

The evidence is accumulating that CO_2 emissions abatement will eventually be needed, but there is much uncertainty as to the timing and magnitude. A broad based research program is required to explore a diverse spectrum of options valid for multiple time frames. Therefore, we propose an initial five year research program into the capture and sequestration of CO_2 with the following strategic goals:

- ***Encourage/accelerate near-term opportunities.*** There are some opportunities for commercial scale CO_2 capture that may be able to be developed and implemented now, similar to the Sleipner West project in Norway. Early emission reductions may receive credit for these activities in the event of a mandatory emission reduction program.

- ***Assess the feasibility of CO_2 capture and sequestration technologies.*** Before one can add CO_2 capture and sequestration to the active list of mitigation options, two key questions concerning its feasibility must be answered. First, can we make the technologies cost-effective enough to compete economically? We need much more research to better understand the future mitigation supply curves in terms of both cost and mitigation potential. Secondly, do large-scale storage options exist that are technically feasible and publicly acceptable? While the studies to date suggest cause for optimism, large-scale feasibility has not yet been proven.

- ***Position the US to become a technology leader.*** On the current trajectory, Japan is becoming a research and technology leader for CO_2 capture and sequestration. The research program presented below will provide the US with the option to become a technology leader in this field.

- ***Leverage on-going international research.*** With the current level of funding, it is impossible for the US to monitor and participate in the extensive on-going research activities worldwide. At an expanded level of funding, we can seek international collaboration to leverage our research dollars. One mechanism already in place is the IEA Greenhouse Gas R&D Programme. International collaboration is also inherent in the US-signed Climate Technology Initiative (CTI), which calls for the international research community to "assess the feasibility of developing longer-term technologies to capture, remove or dispose of greenhouse gases and strengthen relevant basic and applied research."

- ***Assess compatibility with on-going advanced combustion and efficiency programs.*** Fossil Energy has a major research program investigating advanced combustion systems. By taking into account the possibility of CO_2 capture and sequestration technologies, these technologies may be more widely adopted when modified for a greenhouse world. The

time to make this assessment is now, so the possibility of CO_2 capture and sequestration can be built into their design.

- ***Stimulate private sector R&D.*** Energy related R&D in both the public and private sectors has been declining. This trend has been accelerated in the utility industry due to deregulation. However, programs can be set up to both stimulate private sector R&D and leverage scarce DOE research dollars. One example is the $5 million, 3 year DOE-PETC/EPRI Cooperative RD&D Agreement.

To date, the cumulative research funding for CO_2 capture and sequestration technologies in the US has been less than $10 million, limiting the research effort to theoretical or laboratory studies. In addition to these types of studies, pilot-scale research in the field is required as part of a proposed five year program to achieve the strategic goals outlined above. However, it is still premature to conduct costly demonstration projects. Decisions on demonstration projects can be made near the end of the proposed research program, when more information will be available concerning the feasibility of CO_2 capture and sequestration technologies, as well as the status of international agreements aimed at limiting greenhouse gas emissions.

We recommend the following specific program components, with their relative share of available funds indicated:

- ***Promotion of near-term opportunities (15%).*** Potential areas include cofiring of biomass, industrial capture (e.g., from oil and gas operations), enhanced oil recovery, and utilization opportunities. This program component can coordinate with on-going DOE industrial initiatives, such as those in the Office of Industrial Technologies. This component should focus on applications that are economically feasible today and that will yield a positive return on investment when implemented.

- ***Assessment and development of capture technology (25%).*** This element needs to focus on three strategies: improving solvents and processes for CO_2 scrubbing from flue gases, developing new power plants based on an oxygen feed, and integrating capture technology into advanced combustion systems including gasifiers and fuel cells. Research on CO_2 solvents should include the private sector which has commercial processes available for related problems.

- ***Assessment and development of storage technology (35%).*** Since the US has the potential to take advantage of all of the major storage options suggested (oil and gas wells, coal beds, aquifers, and the ocean), all should be investigated. Cooperation with the oil and gas industry will be a key component in realistic assessments of geologic storage potential. Major opportunities exist for international collaboration in this research with Japan (oceans), Norway (aquifers), and the Netherlands (oil and gas wells).

- ***System analysis (10%).*** To help guide and focus the research on practical solutions, we need to undertake some general system studies. Questions to be addressed include: What existing sites in the US can take advantage of this technology and at what costs? Since plants built today will last for 50 years or longer, how can we address global change concerns in their design given the uncertainties that exist today? What opportunities exist worldwide for CO_2 capture and sequestration as part of a joint implementation (JI) strategy?

- ***Generation and assessment of longer-term technologies (15%).*** Since CO_2 mitigation is projected to become more difficult in the long-term, we need to start examining some longer-term technologies today. Part of this research will attempt to generate new and creative ideas and to identify the ones with real potential. Perhaps a contest-type program (similar to Golden Carrot[3]) can be used to achieve this goal.

Based on the program outlined above, we recommend a budget that averages $50 million per year for 5 years as detailed below:

FY98 $20 million
FY99 $40 million
FY00 $60 million
FY01 $70 million
FY02 $60 million

We envision a leveraging of this budget through collaboration, both domestically and internationally. Approximately half the research dollars should go to collaborative projects. Domestically, agreements can be modeled on the DOE-PETC/EPRI Cooperative R&D Agreement. Internationally, in addition to the IEA Greenhouse Gas R&D Programme, preliminary negotiations are underway with the Japanese and Norwegians (to collaborate on research into CO_2 storage, both geological and ocean) and the Canadians (to collaborate on CO_2 capture using an oxygen feed).

To put this budget request in perspective, we can make the following comparisons:

- The alternative longer-term mitigation strategies of increased nuclear and renewable energy have had billions of DOE research dollars expended on their development, while research into CO_2 capture and disposal is still in its infancy (less than $10 million spent on research

[3]In 1989, the US EPA, 24 electric utility companies, and the NRDC developed the Super Efficient Refrigerator Program (aka the Golden Carrot program). The program provided a $30 million prize to the winning manufacturer to develop a refrigerator that used no CFCs and boosted appliance efficiency by at least 25% over current standards. This public/private collaborative effort represented a novel "market pull" approach to innovation. The $30 million was distributed as rebates for each refrigerator sold in the utilities service area. Whirlpool was proclaimed the winner and, if the projected sales are met, the new efficient refrigerators will save $75 million in reduced electric bills over their lifetimes.

by DOE). The limited funding to date for CO_2 capture and sequestration has not allowed significant program development, making it difficult to fairly assess the potential of these technologies.

- According to the Energy Information Administration, the total US energy expenditures are approximately $500 billion annually. The existing capital stock of the utility industry worldwide is estimated in excess of $2 trillion. It seems wise to investigate whether CO_2 capture and sequestration technologies can allow fossil fuels to remain a cost-effective energy source, while concurrently contributing to a significant reduction in greenhouse gas emissions.

- On the surface, it seems the magnitude of the proposed program is similar to the Japanese government's effort of the past several years (see Chapter 3). However, when one considers that the Japanese figures presented are only direct costs (no overhead) and the program proposed here is more broadly based, this research program is modest in comparison to the Japanese government expenditures (by at least a factor of 2). In addition to the government programs, Japanese industry funds significant research in this area.

- The US now spends about $1.6 billion annually investigating various aspects of the climate change problem. Spending at that level indicates that global climate change is being taken seriously. It seems prudent to spend at just 3% of that level to investigate one of the few possible longer-term mitigation solutions.

As a next step, a detailed list of prioritized research needs based on the above program components has to be developed. This effort is currently underway at the MIT Energy Laboratory, which has received a grant from DOE to update its 1993 research needs assessment. The report will be completed in September, 1997. After the report is issued, a workshop should be held to design a specific plan of action. In prioritizing the research, the following points will be considered:

- What are the US needs and how do proposed options fit in with US policies? We need to focus on solutions that reflect the US situation. For example, the large role coal plays in generating our electricity (vs. natural gas for Japan). However, because taking advantage of potential JI opportunities may be part of future US policies, we also need to keep a world view.

- Where does the greatest potential lie? While there are no single solutions, we still need to focus on solutions that can have a real impact.

- How risky is the technology? We need practical solutions, so we need to focus on strategies using proven methods for the near- and mid-term. For the longer-term, we can investigate some of the more novel technologies.

- To what extent can the private sector be involved? Where possible, we need to engage the private sector, since this is where these technologies will ultimately be applied.

- Can we leverage existing programs? Where possible, the research should build on existing national and international programs. Nationally, we already mentioned advanced combustion technology development as well as some of DOE's industrial initiatives. Internationally, opportunities exist through the IEA Greenhouse Gas R&D Programme and the CTI, as well as direct bilateral and multilateral collaboration.

11. References

Adams E, D Golomb, X Zhang and H Herzog, "Confined Release of CO_2 into Shallow Seawater", in *Direct Ocean Disposal of Carbon Dioxide* (Handa and Ohsumi, ed.) pp. 153-164 (1995).

Albanese AS and M Steinberg, *Environmental Control Technology for Atmospheric Carbon Dioxide*, DOE/EV-0079, Brookhaven National Laboratory, Brookhaven, NY (1980).

Arashi N, N Oda, M Yamada, H Ota, S Umeda and M Tajika, "Evaluation of Test Results of 1000 m^3N/h Pilot Plant for CO_2 Absorption using an Amine-based Solution", *Energy Convers. Mgmt*., in press (1997).

Aresta M and I Tommasi, "Carbon Dioxide Utilisation in the Chemical Industry", *Energy Convers. Mgmt*., in press (1997).

Arnold DS, A Barrett and RH Isom, "CO_2 Can Be Produced from Flue Gas", *Oil & Gas Journal* **80**(47), pp. 130-136 (1982).

Aroonwilas A and P Tontiwachwuthikul, "Mass Transfer Studies of High Performance Structured Packing for CO_2 Separation Processes", *Energy Convers. Mgmt*., in press (1997).

Auerbach D, "Global Warming Mitigation via Ocean Disposal of Power Plant-Generated CO_2: an Environmental and Political Analysis", MS Thesis, Dept. of Civil and Environ. Engrg., MIT, Cambridge, MA (1996).

Audus H, "IEA Greenhouse Gas R&D Programme: Full Fuel Cycle Studies", *Energy Conv. Mgmt.* **37**(6-8), pp. 837-842 (1996).

Audus H and L Saroff, "Full Fuel Cycle Evaluation of CO_2 Mitigation Options for Fossil Fuel Fired Power Plant", *Energy Convers. Mgmt.* **36**(6-9), pp. 831-834 (1995).

Audus H and H Oonk, "An Assessment Procedure for Chemical Utilisation Schemes Intended to Reduce CO_2 Emissions to the Atmosphere", *Energy Convers. Mgmt*., in press (1997).

Bacastow RB and RK Dewey, "Effectiveness of CO_2 Sequestration in the Post Industrial Ocean", *Energy Convers. Mgmt.* **37**(6-8), pp. 1079-1086 (1996).

Baes CF Jr., SE Beall, DW Lee and G Marland, "Options for the Collection and Disposal of Carbon Dioxide" ORNL-5657, Oak Ridge National Laboratory, Oak Ridge, TN (1980).

Barchas R and R Davis, "The Kerr-McGee/ABB Lummus Crest Technology for the Recovery of CO_2 from Stack Gases", *Energy Convers. Mgmt*. **33**(5-8), pp. 333-40 (1992).

Benemann JR, "CO_2 Mitigation with Microalgae Systems", *Energy Convers. Mgmt*., in press (1997).

Benneman JR and WJ Oswald, *Systems and Economic Analysis of Microalgae Ponds for Conversion of CO_2 to Biomass*, report to DOE/PETC (1996).

Benjamin W, "Biomass Development and Waste Wood Co-Firing", *Energy Convers. Mgmt*., in press (1997).

Bergman PD and EM Winter, "Disposal of Carbon Dioxide in Deep Saline Aquifers in the US", *US/Japan Joint Technical Workshop,* US Dept. Of Energy, Sept. 30 - Oct. 2, State College, PA (1996).

Bergman PD, EM Winter and Z-Y Chen, "Evaluation of CO_2 Disposal in Oil and Gas Reservoirs in Texas", *Energy Convers. Mgmt*., in press (1997).

Blok K, WC Turkenburg, CA Hendriks and M Steinberg, eds., *Proceedings of the First International Conference on Carbon Dioxide Removal*, Oxford: Pergamon Press, 544 pp. (1992).

Bruce J, H Lee and E Haites, eds., *Climate Change 1995 - Economic and Social Dimensions of Climate Change*, Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press (1996).

Caulfield J, "Environmental Impacts of Carbon Dioxide Ocean Disposal: Plume Predictions and Time Dependent Organism Experience", MS Thesis, Dept. of Civil and Environ. Engrg., MIT, Cambridge, MA (1996)

Dawson FM, "Coal bed Methane: A Comparison Between Canada and the United States", *Geological Survey of Canada Bulletin* **489**, 60 pp. (1995).

Doctor RD, JC Molburg, and PR Thimmapuram, *KRW Oxygen-Blown gasification Combined Cycle: Carbon Dioxide Recovery, Transport, and Disposal*, ANL/ESD-34, Argonne National Laboratory, Argonne, IL (1996).

Dopyera C, "The Iron Hypothesis", *Earth*, October, 26-39 (1996).

Dunsmore HE, "A Geological Perspective on Global Warming and the Possibility of CO_2 Removal as Calcium Carbonate Mineral", *Energy Convers. Mgmt.* **33**(5-8), pp. 565-572 (1992).

Farla J, C Hendriks and K Blok, *Carbon Dioxide Recovery from Industrial Processes*, Report No. 92076, Dept. of Science, Technology, and Society, Utrecht University, The Netherlands (1992).

Feron PHM and AE Jansen, “The Production of Carbon Dioxide from Flue Gas by Membrane Gas Absorption”, *Energy Convers. Mgmt*., in press (1997).

Freund P and WG Ormerod, "Progress Toward Storage of Carbon Dioxide", *Energy Convers. Mgmt*., in press (1997).

Golomb D, "Transport Systems for Ocean Disposal of CO_2 and Their Environmental Effects", *Energy Convers. Mgmt*., in press (1997).

Greenbaum E, “Renewable Hydrogen Production for Fossil Fuel Processing”, *US/Japan Joint Technical Workshop*, US Dept. Of Energy, Sept. 30 - Oct. 2, State College, PA (1996).

Gunter WD, EH Perkins and TJ McCann, “Aquifer Disposal of CO_2-rich Gases: Reaction Design for Added Capacity", *Energy Convers. Mgmt* **34**(9-11), pp. 941-948 (1993).

Gunter WD, T Gentzis, BA Rottenfusser and RJH Richardson, "Deep Coal bed Methane in Alberta, Canada: A Fuel Resource with the Potential of Zero Greenhouse Gas Emissions", *Energy Convers. Mgmt.*, in press (1997).

Haugan PM and H Drange, “Sequestration of CO_2 in the Deep Ocean by Shallow Injection”, *Nature*, **357**, pp. 318-20 (1992).

Haugan P and H Drange, "Effects of CO_2 on the Ocean Environment”, *Energy Convers. Mgmt* **37**(6-8), pp. 1019-1022 (1995).

Hendriks C, *Carbon Dioxide Removal from Coal-Fired Power Plants*, Kluwer Academic Press, Dordrecht, The Netherlands (1994).

Herzog H, E Drake, J Tester and R Rosenthal, *A Research Needs Assessment for the Capture, Utilization, and Disposal of Carbon Dioxide from Fossil Fuel-Fired Power Plants*, DOE/ER-30194, US Department of Energy, Washington, DC (1993).

Herzog HJ and EM Drake, *Long-Term Advanced CO_2 Capture Options*, IEA/93/0E6, IEA Greenhouse Gas R&D Programme, Cheltenham, UK (1993).

Herzog HJ, E Adams, D Auerbach and J Caulfield, *Technology Assessment of CO_2 Ocean Disposal*, Report 95-001, MIT Energy Laboratory, Cambridge, MA (1995).

Hitchon B, *Aquifer Disposal of Carbon Dioxide--hydrodynamics and Mineral Trapping: Proof of Concept*, Geoscience Publ. Ltd., Sherwood Park, Alberta, Canada (1996).

Hoffert MI, YC Wey, AJ Callegari and WS Broeker, "Atmospheric Response to Deep-Sea Injections of Fossil-Fuel Carbon Dioxide”, *Climatic Change* **2**(1), pp. 53-68 (1979) .

Holloway S, "Safety of the Underground Disposal of Carbon Dioxide", *Energy Convers. Mgmt.*, in press (1997).

Hopson S, "Amine Inhibitor Copes with Corrosion", *Oil & Gas Journal* **83**(26), pp. 44-47 (1985).

Horiuchi K, T Kojima and A Inaba, "Optimization of Fertilization of Nutrients to the Ocean Taking into Account Horizontal Diffusion and Fixation by Phytoplankton", *Energy Convers. Mgmt.*, in press (1997).

Hughes E and JR Benemann, "Biological Fossil CO_2 Mitigation", *Energy Convers. Mgmt.*, in press (1997).

Hunt E, DE Prinzing, JJ Battista and E Hughes, "A Coal/Power Industry Cooperative Test of Direct Fossil-Fuel CO_2 Mitigation", *Energy Convers. Mgmt.*, in press (1997).

Jarvis PG, "Atmospheric Carbon Dioxide and Forests", *Phil. Trans. R. Soc.*, London B **324**, pp. 369-392 (1989).

Kaarstad O and H Audus, "Hydrogen and Electricity from Decarbonised Fossil Fuels", *Energy Convers. Mgmt.*, in press (1997).

Kadam K, "Power Plant Flue Gas as a Source of CO_2 for Microalgae Cultivation: Economic Impact of Various Process Options", *Energy Convers. Mgmt.*, in press (1997).

Kajishima T, T Saito, R Nagaosa and H Hatano, "A Gas-Lift System for CO_2 Release into Shallow Seawater", *Energy Convers. Mgmt* **36**(6-9), pp. 467-470 (1995).

Kaplan LJ, "Cost-Saving Process Recovers CO_2 from Power-Plant Fluegas", *Chemical Engineering* **89**(24), pp. 30-31 (1982).

Kojima T, A Nagamine, N Ueno and S Uemiya, "Absorption and Fixation of Carbon Dioxide by Rock Weathering", *Energy Convers. Mgmt.*, in press (1997).

Kollek R, "Carbon Dioxide Disposal: Evaluation of a Scheme for Disposing of the CO_2 Product from a 2 GW_e Coal-Fired Power Station in the Ocean at a Depth of 500 m", IEA Greenhouse Gas R&D Programme Report IEA/93/OE13, Cheltenham, UK (1993).

Kondo J, T Inui and K Wasa, eds, *Proceedings of the Second International Conference on Carbon Dioxide Removal*, Oxford: Pergamon Press, 570 pp. (1995).

Kongsjorden H, “Aquifer Storage of Carbon Dioxide in the Sleipner Project”, presented at the *International Symposium on Ocean Disposal of Carbon Dioxide*, NEDO and IEA GHG, Tokyo, Oct. 31 - Nov. 1 (1996).

Korbøl R and A Kaddour, “Sleipner Vest CO_2 Disposal - Injection of Removed CO_2 into the Utsira Formation”, *Energy Convers. Mgmt* **36**(6-9), pp. 509-512 (1995).

Kumar N, RF Anderson, RA Mortlock, PN Froelich, P Kubik, B Dittrich-Hannen and M Suter, “Increased Biological Productivity and Export Production in the Glacial Southern Ocean”, *Nature* **378**, pp. 675-80 (1995).

Lackner KS and DP Butt, “Carbon Dioxide Disposal as Mineral Carbonate”, *Energy Convers. Mgmt.*, in press (1997).

Lake LW, *Enhanced Oil Recovery*, Prentice-Hall, Englewood Cliffs, NJ (1989).

Leci CL, “Development Requirements Necessary for CO_2 Absorption Processes for Effective CO_2 Capture from Power Plants”, *Energy Convers. Mgmt.*, in press (1997).

Lewis NS, “Artificial Photosynthesis”, *Amer. Scientist* **80**, pp. 534-541 (1995).

Lindeberg E, “Escape of CO_2 from Aquifers", *Energy Convers. Mgmt*., in press (1997).

Liro C, E Adams and H Herzog "Modeling the Release of CO_2 in the Deep Ocean", *Energy Convers. Mgmt* **33**(5-8), pp. 667-674 (1992).

Magnesen T and T Wahl, "Biological Impact of Deep Sea Disposal of Carbon Dioxide", The Nansen Environmental and Remote Sensing Center (NERSC) Technical Report No. 77A, Bergen, Norway (1993).

Marchetti C, "On Geoengineering and the CO_2 Problem”, *Climatic Change* **1**(1), pp. 59-68 (1977).

Martin J, *J. Paleoceanography* **5**, pp. 1-13 (1990).

Masutani SM, CM Kinoshita, GC Nihous, H Teng, LA Vega and SK Sharma, "Laboratory Experiments on CO_2 Injection into the Ocean", in: *Direct Ocean Disposal of Carbon Dioxide* (Handa and Ohsumi, ed.), pp. 239-252 (1995).

McGowin CR and EE Hughes, “Clean Energy from Waste and Coal”, in *Amer. Chem. Soc. Symp. Series No. 515*, p. 14 (1992).

Messner S, “Synergies and Conflicts of Sulfur and Carbon Mitigation Strategies”, *Energy Convers. Mgmt*., in press (1997).

Mimura T, H Simayoshi, T Suda, M Iijima and S Mituoka, “Development of Energy Saving Technology for Flue Gas Carbon Dioxide Recovery by Chemical Absorption Method and Steam System in Power Plant”, *Energy Convers. Mgmt*., in press (1997).

Miura Y, T Akano, K Fukatsu, H Miyasaka, T Mizoguchi, K Yagi, I Maeda, Y Ikuta and H Matsumoto, “Stably Sustained Hydrogen Production by Biophotolysis in Natural Day/Night Cycle”, *Energy Convers. Mgmt*., in press (1997).

Myers FS, "Japan Bids for Global Leadership in Clean Industry”, *Science*, **256**, pp. 1144-1145 (1992).

Nakashiki N, T Ohsumi and K Shitashima, "Sequestering of CO_2 in a Deep Ocean -- Fall Velocity and Dissolution Rate of Solid CO_2 in the Ocean", CRIEPI Report (EU 91003), Japan (1991).

National Academy of Sciences (NAS), *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base*, National Academy Press, Washington, DC (1992).

Oak Ridge National Laboratory (ORNL), *Estimating Fuel Cycle Externalities: Analytical Methods and Issues*, Vol 2, prepared by ORNL an Resources for the Future for DOE under contract DEAC0584OR21400 (1994).

Ohsumi T, "CO_2 Disposal Options in the Deep Sea", *Marine Technology Society Journal*, **29**(3), pp. 58-66 (1995).

Ohtaguchi K, S Kajiwara, D Mustaqim and N Takahashi, “Cyanobacterial Bioconversion of Carbon Dioxide for Fuel Production”, *Energy Convers. Mgmt*., in press (1997).

Ormerod W, *The Disposal of Carbon Dioxide from Fossil Fuel Fired Power Stations*, IEAGHG/SR3, IEA Greenhouse Gas R&D Programme, Cheltenham, UK (1994).

OTA, *Enhanced Oil Recovery Potential in the United States*, Office of Technology Assessment, Washington D.C. (1978).

Ozaki M, K Sonoda, Y Fujioka, O Tsukamoto, and M Komatsu, “Sending CO_2 into Deep Ocean with a Hanging Pipe from Floating Platform”, *Energy Convers. Mgmt.* **36**(6-9), pp. 475-78 (1995).

Ozaki M, “Vertical Pipelines from Platforms and Moving Ships”, in *Ocean Storage of CO_2 - Workshop 4 Practical and Experimental Approaches*, IEA Greenhouse Gas R&D Programme, Cheltenham, UK, in press (1997).

Palmer A, “Deep Water Pipelines”, , in *Ocean Storage of CO_2 - Workshop 4 Practical and Experimental Approaches*, IEA Greenhouse Gas R&D Programme, Cheltenham, UK, in press (1997).

Pauley CP, PL Simiskey and S Haigh, "N-ReN Recovers CO_2 from Flue Gas Economically”, *Oil & Gas Journal* **82**(20), pp 87-92 (1984).

Richels R and J Edmonds, “The Economics of Stabilizing Atmospheric CO_2 Concentrations”, *Energy Policy* **23**(4-5), pp. 373-377 (1995).

Riemer PWF, ed., *Proceedings of the International Energy Agency Carbon Dioxide Disposal Symposium*, Oxford: Pergamon Press, 517 pp. (1993).

Riemer PWF and AY Smith, eds., *Proceedings of the International Energy Agency Greenhouse Gas: Mitigation Options Conference*, Oxford: Pergamon Press, 728 pp. (1996).

Robertson T and H Shapouri, *Proc. First Biomass Conf. of the Americas*, NREL/CP-200-5768 DE 93010050, National Renewable Energy Laboratory, Golden, CO (1993).

Rosen MA and DS Scott, “Analysis of the Efficiencies of Several Hydrogen Production Processes”, *Hydrogen Energy Progress XI*, Proc. of the 11th World Hydrogen Energy Conf., Stuttgart, **1**, pp. 479-488 (1996).

Sampson RN, GA Moll and JJ Kelbaso, “Opportunities to Increase Urban Forests and Potential Impacts of Carbon Storage and Conservation”, in *Forests and Global Change*, Vol. 1 (RN Sampson, ed.), American Forests, Washington DC, pp. 51-72 (1992).

Sander MT and CL Mariz, "The Fluor Daniel Econamine FG Process: Past Experience and Present Day Focus”, *Energy Convers. Mgmt*. **33**(5-8), pp. 341-48 (1992).

Sarmiento JL, “Ocean Carbon Cycle”, *C&EN*, pp. 30-43, May 31 (1993).

Saroff L, “Coal Fuel Cycle Externalities Estimates”, *Energy Conv. Mgmt.* **37**(6-8), pp. 1241-1246 (1996).

Steinberg M, *An Analysis of Concepts for Controlling Atmospheric Carbon Dioxide*, DOE/CH/00016-1, Brookhaven National Laboratory, Brookhaven, NY (1984).

Steinberg M, “Production of Hydrogen and Methanol from Natural Gas with Reduced CO_2 Emission”, *Hydrogen Energy Progress XI*, Proc. of the 11th World Hydrogen Energy Conf., Stuttgart, **1**, pp. 499-510 (1996).

Tek MR, ed., *Underground Storage of Natural Gas: Theory and Practice*, NATOASI Series E: Applied Sciences Vol. 171, Kluwer, Boston (1989).

Usui N and M Ikenouchi, "The Biological CO_2 Fixation and Utilization Project by RITE (1) -- Highly-effective Photobioreactor System", *Energy Convers. Mgmt*., in press (1997).

Watson RT, MC Zinyowera and RH Moss, eds., *Climate Change 1995 - Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses,* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press (1996).

Webster IC, "IEA Greenhouse Gas Programme: Continued International Collaboration", *Energy Convers. Mgmt.* **36**(6-9), pp. 865-68 (1995).

Williams RH, *Fuel Decarbonization for Fuel Cell Applications and Sequestration of the Separated CO_2,* PU/CEES report No. 295, Center for Energy and Environmental Studies, Princeton University, Princeton, NJ (1996).

Wilson TRS, "The Deep Ocean Disposal of Carbon Dioxide", *Energy Convers. Mgmt.*, **33**(5-8), pp. 627-33 (1992).

Wiltsee GA Jr., CR McGowin and EE Hughes, "Biomass Conversion Technologies for Power generation", *Proc. First Biomass Conf. Of the Americas*, National Renewable Energy Laboratory, Golden, CO, NREL/CP-200-5768 DE 93010050, pp. 347-367, 1993.

Winter EM and PD Bergman PD, "Potential for Terrestrial Disposal of Carbon Dioxide in the US", *US/Japan Joint Technical Workshop,* US Dept. Of Energy, Sept. 30 - Oct. 2, State College, PA (1996).

Yokoyama S, "Potential Land Area for Reforestation and Carbon Dioxide Mitigation Effect through Biomass Energy Conversion", *Energy Convers. Mgmt*., in press (1997).

Appendices

A. Current DOE Initiatives Which Address Greenhouse Gas Emissions

Clean Coal Technology. The growing concern of global climate change is being addressed in part through the demonstration of high-efficiency advanced electric power generating technologies. Under the Clean Coal Technology (CCT) Demonstration Program nearly 900 MW_e of new capacity and more than 900 MW_e of repowered capacity are represented by 12 projects valued at nearly $3.4 billion. These projects include five fluidized-bed combustion systems, four integrated gasification combined-cycle (IGCC) systems, and three advanced combustion/heat engine systems. These projects will not only provide environmentally sound electric power generation in the mid- to late 1990's, but will also provide the demonstrated technology base necessary to meet new capacity requirements in the 21st century. One system, the integrated gasification fuel cell (IGFC), promises to cut greenhouse gas emissions by over 50% in comparison to conventional operating plants. Advanced turbines under development by DOE in another large program will contribute to the overall 70% efficiency expected of the IGFC system.

Under another program, development control devices and pilot-scale, advanced power systems will be demonstrated at the Power Systems Development Facility in Wilsonville, AL, beginning in 1997 through the year 2002 at a cost of $231 million. Specifically there appears to be a gap between the years 2000 and 2015 which offers the opportunity to build second generation, integrated advanced power systems incorporating CO_2 control and lessons learned from the initial demonstration projects.

The Climate Change Action Plan. In April 1993, President Clinton announced the US commitment to return GHG emissions in 2000 to their 1990 levels. President Clinton also instructed his Administration to prepare an action plan to achieve this goal and continue the trend of reduced emissions. The Climate Change Action Plan (CCAP), published in October, 1993, consists of about 50 distinct but interrelated federal initiatives. A majority of these initiatives seek to reduce or avoid GHG emissions via influencing patterns of energy demand and supply. In addition, special programs are also employed for methane emission reduction and recovery, reduction of minor GHGs (HFC, PFC, and N_2O), and enhancement of carbon sequestration via forestry actions.

The centerpiece of the utilities' response to the climate change issue is the "Climate Challenge" program. Climate Challenge is a joint initiative between the US Department of Energy (DOE) and the electric utility industry to voluntarily reduce greenhouse gas emissions. The initiative, announced as a foundation action under the Climate Change Action Plan, consists of voluntary commitments by electric utilities to undertake actions to reduce, avoid, offset or sequester GHG emissions. As a partnership between DOE and the electric utilities, Climate Challenge utilities are moving to reduce their GHG emissions using a wide range of emission reduction options and innovative approaches.

Climate Challenge commitments are formalized in individual Participation Accords with the utilities. These Participation Accords contain specific commitments describing the actions that the utility and DOE have each committed to undertake under the Climate Challenge Program. The types of commitments are broad enough that any utility can participate, whether large or small, with or without generation facilities, and having all kinds of resource mixes and load growth. "Flexibility" is a key word in all of these efforts. The participants agree to periodically report their individual progress and the obstacles that they have encountered, and they can modify the accords as needed.

As of November 1996, about 600 electric utilities had signed 114 Participation Accords with DOE, specifying the actions they would be taking. These utilities represent over 60% of 1990 US electric utility generation and utility carbon emissions. As additional utilities enter into Participation Accords with DOE, the share of the industry's generation and carbon emissions covered by Climate Challenge utilities will continue to rise.

In the Participation Accords so far signed, the Climate Challenges utilities are pledging a wide range of GHG reduction activities, in aggregate about 44 million metric tons of carbon equivalent. About half of the pledged GHG reductions stem from supply-side activities, coming as the result of improvements in nuclear plant availability, improved fossil generation efficiency, renewable energy sources, transmission and distribution modifications, fuel switches to natural gas from coal and oil, and others. Substantial GHG reductions are also pledged from demand-side management programs, landfill and coal bed methane capture, forest carbon programs, international programs, and others.

Climate Challenge is still in its infancy, not quite three years old. Yet in that brief time, it has garnered the support of most of the electric utility industry, demonstrated the value of voluntary and flexible approaches, and is making a substantial contribution to the Administration's Climate Change Action Plan.

B. Calculating the Cost of Mitigation

As further documentation of the numbers presented in the cost discussion of Chapter 3, attached are two tables documenting our sources and calculations. Table B1 shows how we calculated costs for CO_2 capture and sequestration options. The calculational procedure is explained further in Chapter 4, Box 3. Table B2 shows our sources for costs of nuclear and renewable energy technologies and some notes on the calculational assumptions. Some further observations on the data follow:

- The negative values for the cost of end-use energy efficiency are controversial. While they are measured against a relatively higher delivered cost of electricity, they do not include the costs in overcoming potential market imperfections, which make it unlikely that the stated cost and emission reduction potential will be realized.

- The reduction potential of gas assumes that all existing coal plants will be replaced by natural gas combined cycle plants. While this is the maximum technical potential, the achievable potential will be much less. The same argument can be applied to most of the reduction potential numbers.

- The NAS study did not assign a mitigation potential for geothermal due to resource constraints. However, we disagree with this conclusion and have supplied our own geothermal data.

- Reviewers of this paper drew our attention to studies that show much higher prices for forestation and nuclear energy. This highlights the controversy associated in doing this type of analysis. It is not the purpose of this report to arbitrate these differences. Suffice it to say that we recognize that even though we reported a large range of costs, there are still outliers.

As mentioned in Chapter 3, the data presented is very dependent on the assumptions that go into the analysis, which leads to a high level of uncertainty. Therefore, we felt we could only credibly draw the following two conclusions from this data:

- The current and projected costs for CO_2 capture and sequestration are similar to those for nuclear and renewable energy.

- There are a set of "least-regrets" options that are relatively inexpensive, but also may be limited in terms the amount of CO_2 they can mitigate.

To use these numbers for any other purposes, we strongly recommend referencing the original sources.

Table B1. Cost of CO_2 Capture and Sequestration

Case ID High/Low		Storage High	Storage Low	Utilization High	Utilization Low	EOR High	EOR Low	Industrial High	Industrial Low
Energy Penalty		35%	15%	35%	15%	35%	15%	35%	15%
Disposal Costs ($/tonne captured)		$15.00	$5.00	-$35.00	-$35.00	-$12.00	-$12.00	$15.00	$5.00
Electricity Costs in cents/kWh	No Capture	Capture	Capture	Capture	Capture	Capture	Capture	Capture	Capture
Base Generating Cost	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Capture Cost	0	1.35	0.85	1.35	0.85	1.35	0.85	0.68	0.43
Subtotal (per kWh gross)	4.6	5.95	5.45	5.95	5.45	5.95	5.45	5.275	5.025
Net Power (MW)	500	325	425	325	425	325	425	325	425
Subtotal (per kWh net)	4.6	9.15	6.41	9.15	6.41	9.15	6.41	8.12	5.91
T&D, etc.	2	2	2	2	2	2	2	2	2
Total Delivered Cost	6.6	11.15	8.41	11.15	8.41	11.15	8.41	10.12	7.91
CO2 emitted (kg/s)	115	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
CO2 emitted (kg/kWh)	0.828	0.127	0.097	0.127	0.097	0.127	0.097	0.127	0.097
Cost of Capture ($/tonne avoided)		$65	$25	$65	$25	$65	$25	$50	$18
Cost of Disposal ($/tonne avoided)		$26	$6	-$60	-$42	-$20	-$14	$26	$6
Total ($/tonne avoided)		$91	$31	$5	-$17	$45	$10	$76	$24
Impact (million tonnes)	1700	1500	1500	20	20	50	50	80	80

See Box 3 for additional documentation.

Table B2. Cost of CO_2 Mitigation from Nuclear and Renewable Energy

Mitigation Option	Net Cost (NAS, 1992) **($/ton avoided)[A]**	**Net Cost Calculated ($/ton avoided)[B]**	**Future Cost Calculated ($/ton avoided)[C]**	**Low**	**High**
Nuclear	13 - 61	17[1]		13	61
Biomass	16 - 30	8[2] - 42[3]		8	42
Hydroelectric	25	25[4] - 38[3]		25	38
Wind	19-125	26[5]-50[4]	(3.6)[4] - 23[2]	0	125
Solar Photovoltaic	82	26[2] - 400[4]	23[5] - 76[4]	23	400
Solar Thermal	130	88[4] - 178[2]	24[D,2]- 68[4]	24	178
Geothermal		0[6] - 144[6]	15[2]	0	144

Notes:

A. Net costs based on 1989 dollars and 1989 fuel and electricity use. Calculational method based on EPRI's Technical Assessment Guide (1989). The costs are based on 6% discount rate. High and low cost estimates are based on discount rates of 3% and 10% and uncertainty across different studies. Results normalized to an average generating cost of 3.5¢/kWh_e and an average emission factor of .828 kg CO_2/kWh_e.

B. Calculated costs based on 1990 dollars, an average generating cost of 3.5¢/kWh_e, and an average emission factor of .828 kg CO_2/kWh_e. Sources of data for each calculation is referenced.

C. Projected for year 2010.

D. Central receiver technology only.

References:

[1]OECD/IEA, *Renewable Sources of Energy*, (1987).

[2]US DOE, *The Potential of Renewable Energy An Interlaboratory White Paper*, DE 90000322, (1990).

[3]Rubin ES, RN Cooper, RA Frosch, TH Lee, G Marland, AH Rosenfeld and DD Stine, "Realistic Mitigation Options for Global Warming", *Science* **257**, pp. 148-9, 261-6, July 10 (1992).

[4]Sokolinski A, *A review of the Cost Estimates for Selected Backstop Technologies*, MIT (1994).

[5]Alliance to Save Energy, *America's Energy Choices. Investing in a Strong Economy and a Clean Environment*, (1991).

[6]Pabich W, *Hydrothermally-Generated Electricity in the United States: An Industry Analysis*, MIT (1994).

U.S. DEPARTMENT OF ENERGY
FEDERAL ENERGY TECHNOLOGY CENTER
REPORTING REQUIREMENTS CHECKLIST

1. AWARDEE: TBD

2. IDENTIFICATION NUMBER: DE-RA26-98FT35008

3. REPORT SUBMISSION ADDRESS: All required report deliverables are identified with an X and are to be submitted in an electronic form to the following address: U.S. Department of Energy, Federal Energy Technology Center - Morgantown, ATTN: Contractor Reports Receipt Coordinator, M/S F07, P.O. Box 880, 3610 Collins Ferry Road, Morgantown, WV 26507-0880.

4. PLANNING AND REPORTING REQUIREMENTS:

	FORM NO. (See 6.a.)	FREQ.	FILE NAME CHAR.
A. GENERAL MANAGEMENT			
☒ Management Plan	None	X,O,C	01
☒ Status Report	None	M	02
☐ Summary Report	1332.2		03
B. SCHEDULE/LABOR/COST			
☒ Milestone Schedule/Plan	1332.3	X,O,C	10
☒ Labor Plan	1332.4	X,O,C	11
☒ Cost Plan	1332.7	X,O,C	12
☐ Milestone Schedule/Status	1332.3		13
☐ Labor Management Report	1332.8		14
☒ Cost Management Report	1332.9	M	15
C. EXCEPTION REPORTS			
☐ Conference Record	None		20
☒ Hot Line Report	None	A	21
D. PERFORMANCE MEASUREMENT			30
☐ Management Control System Description			
☐ WBS Dictionary			
☐ Index			
☐ Element Definition			
☐ Cost Performance Reports			
☐ Format 1 — WBS			
☐ Format 2 — Function			
☐ Format 3 — Baseline			

	FORM NO. (See 6.a.)	FREQ.	FILE NAME CHAR.
E. TECHNICAL (See 6.b.)			
☒ Progress/Final Report			
☒ Draft for Review	None	F	40
☒ Final for Approval	None	F	41
☒ Topical Report			
☒ Draft for Review	None	A	42
☒ Final for Approval	None	A	43
F. ENVIRONMENTAL			
☐ Hazardous Substance Plan	None		50
☐ Hazardous Waste Report	None		51
☐ Environmental Compliance Plan	None		52
☐ Environmental Monitoring Plan	None		54
☐ Environmental Status Report	None		54
G. PROPERTY REPORTS			
☒ Semi-Annual Property Report	DOE F 4300.3	A	60
☒ High Risk Personal Property Report	None	A	61
☒ Final Property Report	See Text	A	62
H. OTHER			
☐ Key Personnel Staffing Report	None		70
☒ Subcontracting Report	SF 294	A	71
☒ Summary Subcontract Report	SF 295	A	72
☐ Software			73
☐ Other _____			74

5. FREQUENCY CODES AND DUE DATES:

Definition	Days Due After Event
A - As Required	*
C - Contract Change	15
F - Final - End of Effort	0
Technical Report - Draft Version	- 60
Final Version	0
M - Monthly (End of 1-Month Period)	25
O - Once After Award	30
Q - Quarterly (End of Calendar Quarter)	30
Technical Progress Report - Draft Version	30
Final Version	60**

Definition	Days Due After Event
S - Semiannual (End of Half Calendar Year)	30
Technical Progress Report - Draft Version	30
Final Version	60**
X - With Proposal/Bid/Application	0
Y - Yearly (End of Calendar Year)	30***
Technical Progress Report - Draft Version	30
Final Version	60**

* For due date of Hot Line Report, Property Reports, Environmental Reports, and Subcontracting Reports, see attached text.
** When a draft version is not required, the final version is due when the draft version would have been due.
*** The yearly plans, identified in Sections 4A and 4B, are due by September 15 for the following Federal fiscal year.

6. SPECIAL INSTRUCTIONS:

a. The forms identified in the checklist are available from the cognizant Contract Specialist. Alternate formats are acceptable provided the contents remain consistent with the DOE form.
b. FETC Form 1332.1 "Request for Patent Clearance for Release of Contracted Research Documents" shall be submitted with all technical reports.

J.001b MANAGEMENT PLAN -- ALTERNATE I

The "Management Plan" describes the contractor's approach to performing the effort and producing the products identified in the contractual agreement, and the technical, schedule, cost, and financial management control systems to be used to manage that performance. The content and level of detail in the "Management Plan" vary with the type of contractual agreement and the nature of the work involved; however, it must be sufficiently comprehensive to describe the planned execution, management, and results of the work. The Management Plan shall include:

A. A brief consolidated executive summary permitting general management to quickly comprehend the most significant components of the plan. This summary should be sufficient to present a comprehensive overview of the project and should stress the logical interrelationships among the significant planned components.

B. A brief introduction including a background (e.g., legislative, scientific, sociological, and historical) that discusses the contractor's understanding of the problems, both management and technical, associated with the effort.

C. An overall description of planned accomplishments, including technical, schedule, cost, and financial results, and how they interrelate.

D. A detailed Work Plan, which shall include an identification and schedule of major milestones and major decisions. The Work Plan shall be subdivided into work elements of sufficient detail to identify each and every essential and significant accomplishment necessary for completion of the Statement of Work. The work elements shall be arranged in a block diagram to form a Work Breakdown Structure. Each work element shall be assigned a number according to a logical and comprehensive numbering system. Each work element in this Work Breakdown Structure shall be defined in a Work Breakdown Structure Dictionary. A Network Diagram such as Program Evaluation and Review Technique (PERT) or Critical Path Method (CPM) shall be used to represent the interrelationships of work elements and their relationship to the Statement of Work major accomplishments. The cost and schedule of each of these work elements must be planned for the ensuing year. For succeeding years a cost and schedule plan at the subtask level will suffice.

E. A detailed test plan for technical efforts that involve testing of a technology. At a minimum, the test plan shall include objectives of the tests, description of test equipment and experimental setup, test procedures, test conditions, number of tests, duration of tests, data to be collected, description of equipment used for data collection, description of processing and interpretation of data, and criteria for determining the "success" of a test.

The contractor shall discuss quality assurance programs that will be implemented to ensure quality data from the project.

F. A description of the management systems employed to control cost and schedule performance, including a discussion of the organization components responsible for cost and schedule management, and an explanation of planning, budgeting, accounting, and analytical procedures and systems.

G. A description of the technical support systems and controls employed to enable and control the planned technical results, including systems engineering, configuration management, quality assurance, safety engineering, environmental engineering, data processing, and any other systems, as applicable.

H. A description of the administrative support systems and controls employed to facilitate execution of the contract. The description should include an overview of those systems that support general corporate efforts but which are not dedicated to specific project activities.

J.002 STATUS REPORT

The "Status Report" is the contractor project manager's concise narrative assessment of the status of the work being performed under the contractual agreement. DOE management uses the report to monitor status and to provide early recognition of potential problem areas. The report highlights changes to objectives, changes to technical approach, task variances from baselines in excess of stipulated thresholds by reporting element, causative factors, and actions taken or proposed to resolve them, as well as factors with potential for causing significant variances in the future. Task progress may also be highlighted. The report next identifies open items requiring action by DOE or the contractor. The report also provides a summary assessment of the current situation, including a forecast of the near future and the expected impact on project accomplishment. The report may be accompanied by attachments, including funding status, funding by time period, and a cost change reconciliation.

J.004 MILESTONE SCHEDULE/PLAN

The "Milestone Schedule Plan/Status Report" (DOE F 1332.3) is a dual purpose form to be used first as a baseline plan and then as a status report (see J.007). When used as the "Milestone Schedule Plan," it establishes the contractor's time schedule for accomplishing the planned events and milestones for each reporting category identified in the contract. It encompasses each line item or task required by the contract. Standard symbols and charting conventions described on the reverse side of the form are used to chart the intermediate events and milestones of each reporting category. A "Milestone Log," which is included as an attachment to the "Milestone Schedule Plan/Status Report," lists

intermediate events and critical milestones with the element code, descriptive name of the event or milestone, and the scheduled date of completion. If both this report and a Management Plan are requested (i.e., Clause J.001a, if applicable), this report should be included with the Management Plan.

J.005 LABOR PLAN (JUN 1986)

The "Labor Plan" (DOE F 1332.4) establishes the planned utilization of labor for the term of the contract and addresses the total labor to be utilized to perform the work. It itemizes labor requirements for prior fiscal years, the current fiscal year by month, and future fiscal years until contract completion. If both this report and a Management Plan are requested (i.e., Clause J.001, if applicable), this report should be included with the Management Plan.

J.006 COST PLAN (JUN 1986)

The "Cost Plan" (DOE F 1332.7) establishes the plan for accruing total costs for the life of the contractual agreement. The time-phased baseline plan establishes the basis for the measurement of actual cost accumulation and provides basic information for updating and forecasting budget requirements. The "Cost Plan" itemizes accrued costs for prior fiscal years, the current fiscal year by month, and future fiscal years until completion of the contractual agreement. If both this report and a Management Plan are requested (i.e., Clause J.001, if applicable), this report should be included with the Management Plan.

J.009 COST MANAGEMENT REPORT (JUN 1986)

The "Cost Management Report" (DOE F 1332.9) is a periodic report of the cost status of the contractual agreement to be compared with the "Cost Plan" (see J.006). Both DOE and contractor management use it for monitoring, controlling, and planning allocation of dollar resources. This form contains actual cost status for the reporting and prior periods, and estimates of dollar costs for the remainder of the fiscal year and the balance of the effort.

J.011 HOT LINE REPORT (NOV 1991)

A. The "Hot Line" Report may be used to report a major breakthrough in research, development, or design; an event causing a significant schedule slippage or cost overrun; an environmental, safety and health violation; achievement of or failure to achieve an important technical objective; or any requirement for quickly documented direction or redirection. The report shall be submitted by the most rapid means available, usually electronic, and should confirm telephone conversations with DOE representatives.

Identification as a "Hot Line Report" serves notice at each link in the delivery chain that speed in handling is required. Unless otherwise agreed by the parties involved, DOE is expected to take action and respond in a similarly speedy manner. The report should include:

1. Contractor's name and address;
2. Contract title and number;
3. Date;
4. Brief statement of problem or event;
5. Anticipated impacts; and
6. Corrective action taken or recommended.

B. Hot Line Reports shall document the incidents listed below, in addition to those contained in Paragraph A:

1. Any single fatality or injuries requiring hospitalization of five or more individuals is to be immediately reported.

2. Any significant environmental permit violation is to be reported as soon as possible, but within 24 hours of the discovery of the incident.

3. Other incidents that have the potential for high visibility in the media are to be reported as quickly as possible, but within 24 hours following discovery.

4. Any failure resulting in damage to Government-owned equipment in excess of $50,000 is to be reported as quickly as possible, but within 24 hours of the discovery of the failure.

5. Any unplanned event which is anticipated to cause a schedule slippage or cost increase significant to the project is to be reported within 24 hours.

6. Any verbal or written Notice of Violation of any Environmental, Safety, and Health statutes arising from the performance of this contract is to be immediately reported.

7. Any accidental spill or release which is in violation of any Environmental, Safety, and Health statutes arising from the performance of this contract is to be immediately reported, but within 24 hours of the discovery of the accident.

8. Any incident which causes a significant process or hazard control system failure, or is indicative of one which may lead to any of the above defined incidents, is to be reported as soon as possible, but within 5 days of discovery.

C. The requirement to submit Hot Line Reports for the incidents identified in B.1, B.2, B.3, B.6, or B.7 is for the sole

purpose of enabling DOE officials to respond to questions relating to such events from the media and other public.

D. When an incident is reported in accordance with B.4, B.5, B.6, B.7, or B.8, the contractor shall conduct an investigation of its cause and make an assessment of the adequacy of resultant action. A written report is required no later than ten (10) calendar days following the incident and shall include an analysis of the pertinent facts regarding the cause, and a schedule of the remedial events and time periods necessary to correct the action.

E. When an event results in the need to issue a written or verbal statement to the local media, the statement is to be cleared first, if possible, by the METC Office of Institutional Development and coordinated with the COR and Contracting Officer.

J.013 TECHNICAL REPORTS -- GENERAL (JUN 1986)

Each report of a scientific, technical, and engineering information nature should begin with a statement of the original objective of the effort and a concise summary of the progress achieved during the reporting period. The body of the report should contain a full account of progress, problems encountered, plans for the next reporting period, and an assessment of the prospects for future progress. The author(s) of the report should clearly identify technical factors which affect, either positively or negatively, plans for achieving the objectives on schedule and within the funds available.

The report should include sufficient detail to allow the work to be reproduced by others. Each report should include a thorough account of activities directed toward application of the results, such as investigation of user needs, work or collaboration with potential users, and activities to disseminate the results. It should also include a discussion of how these activities have affected the course of the project, and may include utilization activities.

Computer programs and routines with scientific, technical, and technology-related applications developed by the contractor should be discussed in the report and provided to the Energy Science and Technology Software Center under the policies and procedures of DOE Order 1430.1D, Scientific and Technical Information Management.

J.014 TECHNICAL PROGRESS/FINAL REPORT (JUN 1986)

"Technical Progress Reports" summarize the work performed during a specific reporting period and include the technical and scientific results (both positive and negative) of that period. If a draft Technical Progress Report is required, DOE will review the draft report and provide comments within 20 days after receipt from the

contractor. The contractor will then submit the report in final form within 20 days after receipt of DOE's comments.

"Final Reports" are required for all contractual agreements for research and development work. These reports are technical accounts of the total work performed under the contractual agreement. They are comprehensive descriptions of the results achieved and of the investigations undertaken, and they include tabulations of data, figures, photographs, and bibliographic citations in support of the investigations undertaken. Where applicable, they summarize all topical and technical progress reports. The contractor shall deliver a draft copy of the final report sixty (60) days before the completion of the period of performance. The Government shall be allowed thirty (30) days to review the draft copy and to notify the contractor, in writing, of approval or recommended changes. If the Government does not approve or recommend changes within thirty (30) days of receipt of the draft copy, the report shall be deemed approved. The approved final report is due on the contract completion date. Preparation instructions are provided in J.017 below.

J.015 TOPICAL REPORT (JUN 1986)

A "Topical Report" is a comprehensive statement of the technical results of work performed on a specific task or phase of a research and development effort. It can also be a detailed description of scientific or technological advances. If a draft Topical Report is required, DOE will review the draft report and provide comments within 30 days after receipt from the contractor. The contractor will then submit the report in final form within 30 days after receipt of DOE's comments.

J.016 CLARITY OF REPORTS (JUN 1986)

The Government intends to evaluate the acceptability of reports on the basis of their quality with respect to both substantive and presentational considerations. Evaluation of substantive aspects of these submittals will be based upon criteria generally accepted in the relevant technical field. For document presentation, the contractor shall prepare the documents to: (1) explicitly describe and justify assumptions upon which the work is based, addressing what was accomplished, and (2) facilitate evaluation by readers who possess only general technical knowledge. Other factors which will be considered in evaluating presentation aspects of the documents submitted include: format, clarity, spelling and grammar, organization, continuity, completeness, readability, and legibility of illustrations and figures.

J.017 GUIDELINES FOR PREPARATION OF ELECTRONIC VERSIONS OF REPORTS (FEB 1996)

A. Preparation of Reports

1. General. The contractor is responsible for providing all reports that are identified in the Contract Reporting Requirements Checklist. The contractor shall submit an electronic version of each report, including, but not limited to, all text, tables, diagrams, photographs, schematics, graphs, and charts. Reports shall be submitted in the Adobe Acrobat Portable Document Format (PDF).

2. Organization of Technical Reports. The following sections should be included (as appropriate) in technical reports in the sequence shown:

Title Page*
Disclaimer*
Abstract*
Table of Contents*
List(s) of Graphical Materials
Executive Summary*
Introduction*
Results and Discussion*
Conclusion*
References
Bibliography
List of Acronyms and Abbreviations
Appendices (if necessary)

Any section denoted by an asterisk is required.

The Title Page must contain the following information:

Report Title
Type of Report (Annual, Topical, Final, etc.)
Reporting Period (if applicable)
Principal Author(s)
Date (Month and Year) Report was Issued
DOE Award Number (e.g., DE-AC21-96MC12345)

Name and address of submitting organization. (This section should also contain the name and address of significant contractors or subcontractors who participated in the production of the report.)

The Disclaimer must follow the title page, and must contain the following paragraph:

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their

employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; phone orders accepted at (703) 487-4650.

3. Content of Program/Project Management Reports. The content of such reports shall be consistent with the appropriate DOE Form specified in the Contract Reporting Requirements Checklist.

4. Other Documents Not Identified in the Contract Reporting Requirements Checklist (Journal Articles, Conference Papers and Proceedings, etc.). The contractor shall submit an electronic version of each such document, including, but not limited to, all text, tables, diagrams, photographs, schematics, graphs, and charts. Such documents shall be submitted in the Adobe Acrobat Portable Document Format (PDF).

5. Company Names and Logos. Except as indicated in 2 above, company names, logos, or similar material should not be incorporated into reports.

6. Copyrighted Material. Copyrighted material should not be submitted as part of a report unless written authorization to use such material is received from the copyright owner and is submitted to DOE with the report.

7. Measurement Units. The use of the SI Metric System of Units is required as the primary units of measure except where such use is impractical. Primary SI units may be followed by their U.S. Customary Equivalents in parentheses.

B. Electronic Media Standard

1. File Format. Production of high-quality, electronic documents is dependent on the quality of the input that

is provided. Thus, the contractor shall submit an electronic version of all reports in the Adobe Acrobat Portable Document Format (PDF). Each report shall be an integrated file that contains all text, tables, diagrams, photographs, schematics, graphs, and charts.

2. Submission Format. The electronic file(s) shall be submitted to METC via diskette, file transfer protocol (ftp), or CD-ROM. Diskettes or CD-ROMs must be labelled as follows, and if the ftp alternative is used, an E-mail message sent in conjunction with the ftp file, or a companion ftp file, must contain the following information:

   DOE Award Number

   Type of Report(s) (Annual Technical, Final Technical, Labor Plan, Cost Management Report, etc.)

   Reporting Period (if applicable)

   Name of submitting organization

   Name, phone number, and fax number of preparer

   For diskettes only: Number of diskettes in set (e.g., 1/3).

   Diskette: Diskettes must be 3.5" double-sided, high-density (1.4 Mbyte capacity). If file compression software is used to transmit a PDF file spanning more than one diskette, PKZIP from PKWare, Inc., is the required compression software.

   ftp: At the contractor's discretion, DOE will provide an unsecure ftp location for electronic transmission of documents. Only final versions of technical reports may be submitted using the ftp alternative.

   CD-ROM: The electronic file(s) may be submitted on an IS09660-format CD-ROM.

3. File Naming. In naming the electronic file, contractors shall use a standard seven-character naming convention for the main file name, and "PDF" as the three-character extension.

   For the main file name, the first five characters are the last five digits from the award number; e.g., for Award Number DE-AC21-96MC12345, the first five characters are 12345.

   The next two characters are the numeric characters that correspond to the type of report. These characters are specified on the Contract Reporting Requirements Checklist;

e.g., 02 is for a Management Status Report, and 40 is for a Draft Technical Progress Report.

Thus, the main file name for a Quarterly Draft Technical Progress Report under Award No. DE-AC21-96MC12345 would be 1234540; the total file name would be 1234540.PDF.

J.024 PROPERTY REPORTS (MAR 1996)

Semi-Annual Property Report

The "Semi-Annual Report of DOE-Owned Plant and Capital Equipment" (DOE F 4300.3) report shall be submitted for report periods ending February 28 and August 31 each year. The due dates for these reports are April 15 and October 15, respectively. See FAR 45.5 and DEAR 945.5 for description and format.

High Risk Personal Property Report

A report of Government-owned high risk property shall be submitted annually for the period ending August 31. The due date for this report is October 15. See DOE PMR 109-1.53 "Management of High Risk Property" for description.

Final Property Report

A report of all Government-owned property shall be submitted upon completion or termination of award. See FAR 45.5/.6 and DEAR 945.5/.6 for description.

J.026 SUBCONTRACTING REPORT (MAR 1996)

The "Subcontracting Report for Individual Contracts" (SF 294) shall be submitted semi-annually and is due by the 30th day of the month following the close of the reporting periods (due April 30 and October 30).

J.027 SUMMARY SUBCONTRACT REPORT (MAR 1996)

The "Summary Subcontract Report" (SF 295) shall be submitted annually and is due 30 days after the close of the Government fiscal year (due October 30).

LIST OF GOVERNMENT PROPERTY -- CONTRACTOR ACQUIRED

Phase I -- Contractor Acquired Property

(To Be Determined)

Phase II -- Contractor Acquired Property

(To Be Determined)

Phase III -- Contractor Acquired Property

(To Be Determined)

J.028 INTENTION TO PROPOSE (APR 1984)

Intention to Propose

PRDA Number: DE-RA26-98FT35008

_____ We do intend to submit a proposal.

_____ We do not intend to submit a proposal for the following reasons:

_____

_____

_____

_____

Name and Address of Firm of Organization (Include Zip Code):

_____

_____

_____

_____

Authorized Signature: _____

Typed or Printed Name and Title: _____

Date: _____

NOTE: Unless otherwise stated in the PRDA, no other solicitation material should be returned if you do not intend to submit a proposal.

Mail To:

U.S. Department of Energy
Federal Energy Technology Center
ATTN: Raymod R. Jarr
P.O. Box 880
Morgantown, WV 26507-0880

Attachment E

CONTRACT PRICING PROPOSAL COVER SHEET
(Cost or Pricing Data Required)

1. SOLICITATION / CONTRACT / MODIFICATION NUMBER

OMB No.: **9000-0013**
Expires: 09/30/98

2a. NAME OF OFFEROR			3a. NAME OF OFFEROR'S POINT OF CONTACT	3c. TELEPHONE	
2b. FIRST LINE ADDRESS			3b. TITLE OF OFFEROR'S POINT OF CONTACT	AREA CODE	NUMBER
2c. STREET ADDRESS					
2d. CITY	2e. STATE	2f. ZIP CODE			

4. TYPE OF CONTRACT *(Check)*

☐	a. NEW CONTRACT	☐	d. LETTER CONTRACT
☐	b. CHANGE ORDER	☐	e. UNPRICED ORDER
☐	c. PRICE REVISION/ REDETERMINATION	☐	f. OTHER *(Specify)*

5. TYPE OF CONTRACT *(Check)*

☐ FFP ☐ CPFF ☐ CPIF ☐ CPAF

☐ FPI ☐ OTHER *(Specify)*

6. PROPOSED COST *(A + B = C)*

A. COST	B. PROFIT/FEE	C. TOTAL

7. PERFORMANCE

PLACE		PERIOD	
a.		a.	
b.		b.	

8. List and reference the identification, quantity and total price proposed for each contract line item. A line item cost breakdown supporting this recap is required unless otherwise specified by the Contracting Officer. *(Continue on reverse, and then on plain paper, if necessary, use same headings.)*

a. LINE ITEM NO.	b. IDENTIFICATION	c. QUANTITY	d. TOTAL PRICE	e. PROP. REF. PAGE

9. PROVIDE THE FOLLOWING *(If available)*

NAME OF CONTRACT ADMINISTRATION OFFICE			NAME OF AUDIT OFFICE		
STREET ADDRESS			STREET ADDRESS		
CITY	STATE	ZIP CODE	CITY	STATE	ZIP CODE
TELEPHONE	AREA CODE	NUMBER	TELEPHONE	AREA CODE	NUMBER

10. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS WORK? *(If "Yes," identify.)*

☐ YES ☐ NO

11a. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT? *(If "Yes," complete Item 11b.)*

☐ YES ☐ NO

11b. TYPE OF FINANCING *(Check one)*

☐ ADVANCE PAYMENTS ☐ PROGRESS PAYMENTS

☐ GUARANTEED LOANS

12. HAVE YOU BEEN AWARDED ANY CONTRACTS OR SUBCONTRACTS FOR THE SAME OR SIMILAR ITEMS WITHIN THE PAST 3 YEARS? *(If "Yes," identify item(s), customer(s) and contract number(s) on reverse of form.)*

☐ YES ☐ NO

13. IS THIS PROPOSAL CONSISTENT WITH YOUR ESTABLISHED ESTIMATING AND ACCOUNTING PRACTICES AND PROCEDURES AND FAR PART 31, COST PRINCIPLES? *(If "No," explain on reverse of form.)*

☐ YES ☐ NO

14. COST ACCOUNTING STANDARDS BOARD (CASB) DATA *(Public Law 91-379 as amended and FAR PART 30)*

a. WILL THIS CONTRACT ACTION BE SUBJECT TO CASB REGULATIONS? *(If "No," explain in proposal.)*

☐ YES ☐ NO

b. HAVE YOU SUBMITTED A CASB DISCLOSURE STATEMENT (CASB DS-1 or 2)? *(If "Yes," specify in proposal the office to which submitted and if determined to be adequate.)*

☐ YES ☐ NO

c. HAVE YOU BEEN NOTIFIED THAT YOU ARE OR MAY BE IN NONCOMPLIANCE WITH YOUR DISCLOSURE STATEMENT OR COST ACCOUNTING STANDARDS? *(If "Yes," explain in proposal.)*

☐ YES ☐ NO

d. IS ANY ASPECT OF THIS PROPOSAL INCONSISTENT WITH YOUR DISCLOSED PRACTICES OR APPLICABLE COST ACCOUNTING STANDARDS? *(If "Yes," explain in proposal.)*

☐ YES ☐ NO

This proposal is submitted in response to the solicitation, contract, modification, etc., in Item 1 and reflects our best estimates and / or actual costs as of this date and conforms with the instructions in FAR 15.804-6(b)(1), and Table 15-2. By submitting this proposal, the offeror, if selected for negotiation, grants the contracting officer and authorized representative(s) the right to examine, at any time before award, those records, which include books, documents, accounting procedures and practices, and other data, regardless of type and regardless of whether such items are in written form, in the form of computer data, or any other form, or whether such supporting information is specifically referenced or included in the proposal as the basis for pricing, that will permit an adequate evaluation of the proposed

15a. NAME OF OFFEROR *(Type)*	15b. TITLE OF OFFEROR *(Type)*	16. NAME OF FIRM

17. SIGNATURE	18. DATE OF SUBMISSION

TABLE 15-3 INSTRUCTIONS FOR SUBMISSION OF A CONTRACT PRICING PROPOSAL

1. SF 1411 provides a vehicle for the offeror to submit to the Government a pricing proposal of estimated and / or incurred costs by contract line item with supporting information, adequately cross-referenced, suitable for detailed analysis. A cost-element breakdown, using the applicable format prescribed in 7A, B, or C below, shall be attached for each proposed line item and must reflect any specific requirements established by the contracting officer. Supporting breakdowns must be furnished for each cost element, consistent with offeror's cost accounting system.

When more than one contract line item is proposed, summary total amounts covering all line items must be furnished for each cost element. If agreement has been reached with Government representatives on use of forward pricing rates / factors, identify the agreement, include a copy, and describe its nature. Depending on offeror's system, breakdowns shall be provided for the following basic elements of cost, as applicable:

Materials—Provide a consolidated priced summary of individual material quantities included in the various tasks, orders, or contract line items being proposed and the basis for pricing (vendor quotes, invoice prices, etc.).

Subcontracted Items—Include parts, components, assemblies, and services that are to be produced or performed by others in accordance with offeror's design, specifications, or direction and that are applicable only to the prime contract. For each subcontract over $500,000, the support should provide a listing by source, item, quantity, price, type of subcontract, degree of competition, and basis for establishing source and reasonableness of price, as well as the results of review and evaluation of subcontract proposals when required by FAR 15.806.

Standard Commercial Items—Consists of items that offeror normally fabricates, in whole or in part, and that are generally stocked in inventory. Provide an appropriate explanation of the basis for pricing. If price is based on cost, provide a cost breakdown; if priced at other than cost, provide justification for exemption from submission of cost or pricing data, as required by FAR 15.804-3(e).

Interorganizational Transfer (at other than cost)—Explain pricing method used. (See FAR 31.205-26.)

Raw Material—Consists of material in a form or state that requires further processing. Provide priced quantities of items required for the proposal.

Purchased Parts—Includes material items not covered above. Provide priced quantities of items required for the proposal.

Interorganizational Transfer (at cost)—Include separate breakdown of cost by element.

Direct Labor—Provide a time-phased (e.g., monthly, quarterly, etc.) breakdown of labor hours, rates, and cost by appropriate category, and furnish bases for estimates.

Indirect Costs—Indicate how offeror has computed and applied offeror's indirect costs, including cost breakdowns, and showing trends and budgetary data, to provide a basis for evaluating the reasonableness of proposed rates. Indicate the rates used and provide an appropriate explanation.

Other Costs—List all other costs not otherwise included in the categories described above (e.g., special tooling, travel, computer and consultant services, preservation, packaging and packing, spoilage and rework, and Federal excise tax on finished articles) and provide bases for pricing.

Royalties—If more than $250, provide the following information on a separate page for each separate royalty or license fee: name and address of licensor; date of license agreement; patent numbers, patent application serial numbers, or other basis on which the royalty is payable; brief description (including any part or model numbers of each contract item or component on which the royalty is payable); percentage or dollar rate of royalty per unit; unit price of contract item; number of units; and total dollar amount of royalties. In addition, if specifically requested by the contracting officer, provide a copy of the current license agreement and identification of applicable claims of specific patents. (See FAR 27.204 and 31.205-37.)
Facilities Capital Cost of Money—When the offeror elects to claim facilities capital cost of money as an allowable cost, the offeror must submit Form CASB-CMF and show the calculation of the proposed amount (see FAR 31.205-10).

2. As part of the specific information required, the offeror must submit with offeror's proposal, and clearly identify as such, cost or pricing data (that is, data that are verifiable and factual and otherwise as defined at FAR 15.801). In addition, submit with offeror's proposal any information reasonably required to explain offeror's estimating process, including—
   a. The judgmental factors applied and the mathematical or other methods used in the estimate, including those used in projecting from known data; and
   b. The nature and amount of any contingencies included in the proposed price.

3. There is a clear distinction between submitting cost or pricing data and merely making available books, records, and other documents without identification. The requirement for submission of cost or pricing data is met when all accurate cost or pricing data reasonably available to the offeror have been submitted, either actually or by specific identification, to the contracting officer or an authorized representative. As later information comes into the offeror's possession, it should be promptly submitted to the contracting officer. The requirement for submission of cost or pricing data continues up to the time of final agreement on price.

4. In submitting offeror's proposal, offeror must include an index, appropriately referenced, of all the cost or pricing data and information accompanying or identified in the proposal. In addition, any future additions and / or revisions, up to the date of agreement on price, must be annotated on a supplemental index.

5. By submitting offeror's proposal, the offeror, if selected for negotiation, grants the contracting officer or an authorized representative the right to examine those books, records, documents, and other supporting data that will permit adequate evaluation of the proposed price. This right may be exercised at any time before award.

6. As soon as practicable after final agreement on price, but before the award resulting from the proposal, the offeror shall, under the conditions stated in FAR 15.804-4, submit a Certificate of Current Cost or Pricing Data.

7. HEADINGS FOR SUBMISSION OF LINE-ITEM SUMMARIES:

☒ A. New Contracts (including Letter contracts).

☐ B. Change Orders (modifications).

☐ C. Price Revision / Redetermination.

COST ELEMENTS (1)	PROPOSED CONTRACT ESTIMATE—TOTAL COST (2)	PROPOSED CONTRACT ESTIMATE—UNIT COST (3)	REFERENCE (4)

Under Column (1)—Enter appropriate cost elements.

Under Column (2)—Enter those necessary and reasonable costs that in offeror's judgment will properly be incurred in efficient contract performance. When any of the costs in this column have already been incurred (e.g., under a letter contract or unpriced order), describe them on an attached supporting schedule. When preproduction or startup costs are significant, or when specifically requested to do so by the contracting officer, provide a full identification and explanation of them.

Under Column (3)—Optional, unless required by the contracting officer.

Under Column (4)—Identify the attachment in which the information supporting the specific cost element may be found. Attach separate pages as necessary.

U.S. DEPARTMENT OF ENERGY
REPRESENTATIONS, CERTIFICATIONS, AND OTHER STATEMENTS
OF BIDDERS/OFFERORS
SOLICITATION NO. DE-RA26-98FT35008

SECTION K

Various statutes and regulations require Federal agencies to obtain certain representations, certifications, and other statements from bidders/offerors in connection with the award of contracts. To this end, all bidders/offerors submitting a bid/proposal in response to this solicitation must complete certain items identified below, depending on the method of solicitation.

K.001 CONTINGENT FEE REPRESENTATION AND AGREEMENT (APR 1984) (FAR 52.203-4)

A. Representation. The offeror represents that, except for full-time bona fide employees working solely for the offeror, the offeror--

[NOTE: The offeror must check the appropriate boxes. For interpretation of the representation, including the term "bona fide employee," see Subpart 3.4 of the Federal Acquisition Regulation.]

1. [ ] has, [ ] has not employed or retained any person or company to solicit or obtain this contract: and

2. [ ] has, [ ] has not paid or agreed to pay to any person or company employed or retained to solicit or obtain this contract any commission, percentage, brokerage, or other fee contingent upon or resulting from the award of this contract.

B. Agreement. The offeror agrees to provide information relating to the above Representation as requested by the Contracting Officer and, when subparagraph A.1. or A.2. is answered affirmatively, to promptly submit to the Contracting Officer--

1. A completed Standard Form 119, Statement of Contingent or Other Fees, (SF 119); or

2. A signed statement indicating that the SF 119 was previously submitted to the same contracting office, including the date and applicable solicitation or contract number, and representing that the prior SF 119 applies to this offer or quotation.

K.002 TAXPAYER IDENTIFICATION (MAR 1994) (FAR 52.204-3)

A. Definitions. "Common parent," as used in this solicitation provision, means that corporate entity that owns or controls an affiliated group of corporations that files its Federal income tax returns on a consolidated basis, and of which the offeror is a member.

"Corporate status," as used in this solicitation provision, means a designation as to whether the offeror is a corporate entity, an unincorporated entity (e.g., sole proprietorship or partnership), or a corporation providing medical and health care services.

"Taxpayer Identification Number (TIN)," as used in this solicitation provision, means the number required by the IRS to be used by the offeror in reporting income tax and other returns.

B. All offerors are required to submit the information required in paragraphs (c) through (e) of this solicitation provision in order to comply with reporting requirements of 26 U.S.C. 6041, 6041A, and 6050M and implementing regulations issued by the Internal Revenue Service (IRS). If the resulting contract is subject to reporting requirements described in FAR 4.903, the failure or refusal by the offeror to furnish the information may result in a 31 percent reduction of payments otherwise due under the contract.

C. Taxpayer Identification Number (TIN).

( ) TIN: _____
( ) TIN has been applied for.
( ) TIN is not required because:

( ) Offeror is a nonresident alien, foreign corporation, or foreign partnership that does not have income effectively connected with the conduct of a trade or business in the U.S. and does not have an office or place of business or a fiscal paying agent in the U.S.;
( ) Offeror is an agency or instrumentality of a foreign government;
( ) Offeror is an agency or instrumentality of a Federal, state, or local government;
( ) Other. State basis. _____

D. Corporate Status.

( ) Corporation providing medical and health care services, or engaged in the billing and collecting of payments for such services;
( ) Other corporate entity;
( ) Not a corporate entity;
( ) Sole proprietorship
( ) Partnership
( ) Hospital or extended care facility described in 26 CFR 501(c)(3) that is exempt from taxation under 26 CFR 501(a).

E. Common Parent.

( ) Offeror is not owned or controlled by a common parent as defined in paragraph A. of this clause.
( ) Name and TIN of common parent:
Name: _____
TIN: _____

K.003 WOMEN-OWNED BUSINESS (OCT 1995) (FAR 52.204-5)

A. Representation. The offeror represents that it ( ) is, ( ) is not a women-owned business concern.

B. Definition. "Women-Owned Business Concern" as used in this provision, means a concern which is at least 51 percent owned by one or more women; or in the case of a publicly owned business, at least 51 percent of the stock of which is owned by one or more women; and whose management and daily business operations are controlled by one or more women.

K.004 CERTIFICATION REGARDING DEBARMENT, SUSPENSION, PROPOSED DEBARMENT, AND OTHER RESPONSIBILITY MATTERS (MAY 1989) (FAR 52.209-5)

A. 1. The offeror certifies, to the best of its knowledge and belief, that--

(a) The Offeror and/or any of its Principals--

(1) Are ( ) are not ( ) presently debarred, suspended, proposed for debarment, or declared ineligible for the award of contracts by any Federal agency:

(2) Have ( ) have not ( ), within a 3-year period preceding this offer, been convicted of or had a civil judgment rendered against them for: commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, state, or local) contract or subcontract: violation of Federal or state antitrust statutes relating to the submission of offers; or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property; and

(3) Are ( ) are not ( ) presently indicted for, or otherwise criminally or civilly charged by a governmental entity with, commission of any of the offenses enumerated in subdivision A.1.(a)(2) of this provision.

(b) The Offeror has ( ) has not ( ), within a 3 year period preceding this offer, had one or more contract terminated for default by any Federal agency.

2. "Principals," for the purposes of this certification, means officers; directors; owners; partners; and, persons having primary management of supervisory responsibilities within a business entity (e.g., general manager; plant manager; head of a subsidiary, division, or business segment, and similar positions).

This certification concerns a matter within the jurisdiction of an agency of the United States and the making of a false, fictitious,or fraudulent certification may render the maker subject to prosecution under section 1001, title 18, United States Code.

B. The Offeror shall provide immediate written notice to the Contracting Officer if, at any time prior to contract award, the Offeror learns that its certification was erroneous when submitted or has become erroneous by reason of changed circumstances.

C. A certification that any of the items in paragraph A. of this provision exists will not necessarily result in withholding of an award under this solicitation. However, the certification will be considered in connection with a determination of the Offeror's responsibility. Failure of the Offeror to furnish a certification or provide such additional information as requested by the Contracting Officer may render the Offeror nonresponsible.

D. Nothing contained in the foregoing shall be construed to require establishment of a system of records in order to render, in good faith, the certification required by paragraph A. of this provision. The knowledge and information of an Offeror is not required to exceed that which is normally possessed by a prudent person in the ordinary course of business dealings.

E. The certification in paragraph A. of this provision is a material representation of fact upon which reliance was placed when making award. If it is later determined that the Offeror knowingly rendered an erroneous certification, in addition to other remedies available to the Government, the Contracting Officer may terminate the contract resulting from this solicitation for default.

K.005 SMALL BUSINESS PROGRAM REPRESENTATIONS (OCT 1995) (FAR 52.219-1)

A. Representation. The offeror represents and certifies as part of its offer that it [ ] is, [ ] is not a small business concern and that [ ] all, [ ] not all end items to be furnished will be manufactured or produced by a small business concern in the United States, its territories or possessions, Puerto Rico, or the Trust Territory of the Pacific Islands.

B. Definition. "Small business concern," as used in this provision, means a concern, including its affiliates, that is independently owned and operated, not dominant in the field of operation in which it is bidding on Government contracts, and qualified as a small business under the size standards in this solicitation.

C. Notice. Under 15 U.S.C. 645(d), any person who misrepresents a firm's status as a small business concern in order to obtain a contract to be awarded under the preference programs established pursuant to sections 8(a), 8(d), 9, or 15 of the Small Business Act or any other provision of Federal law that specifically references section 8(d) for a definition of program eligibility, shall (1) be punished by imposition of a fine, imprisonment, or both; (2) be subject to administrative remedies, including suspension and debarment; and (3) be ineligible for participation in programs conducted under the authority of the Act.

K.007 CERTIFICATION OF NONSEGREGATED FACILITIES (APR 1984) (FAR 52.222-21)

A. "Segregated facilities," as used in this provision, means any waiting rooms, work areas, rest rooms and wash rooms, restaurants and other eating areas, time clocks, locker rooms and other storage or dressing areas, parking lots, drinking fountains, recreation or entertainment areas, transportation, and housing facilities provided for employees, that are segregated by explicit directive or are in fact segregated on the basis of race, color, religion, or national origin because of habit, local custom, or otherwise.

B. By the submission of this offer, the offeror certifies that it does not and will not maintain or provide for its employees any segregated facilities at any of its establishments, and that it does not and will not permit its employees to perform their services at any location under its control where segregated facilities are maintained. The offeror agrees that a breach of this certification is a violation of the Equal Opportunity clause in the contract.

C. The offeror further agrees that (except where it has obtained identical certifications from proposed subcontractors for specific time periods) it will--

1. Obtain identical certifications from proposed subcontractors before the award of subcontracts under which the subcontractors will be subject to the Equal Opportunity clause;

2. Retain the certifications in the files; and

3. Forward the following notice to the proposed subcontractors (except if the proposed subcontractors have submitted identical certifications for specific time periods):

NOTICE TO PROSPECTIVE SUBCONTRACTORS OF REQUIREMENT FOR CERTIFICATIONS OF NONSEGREGATED FACILITIES.

A Certification of Nonsegregated Facilities must be submitted before the award of a subcontract under which the subcontractor will be subject to the Equal Opportunity clause. The certification may be submitted either for each subcontract or for all subcontracts during a period (i.e., quarterly, semiannually, or annually).

NOTE: The penalty for making false statements in offers is prescribed in 18 U.S.C. 1001.

K.008 PREVIOUS CONTRACTS AND COMPLIANCE REPORTS (APR 1984) (FAR 52.222-22)

The offeror represents that--

A. It [ ] has, [ ] has not participated in a previous contract or subcontract subject either to the Equal Opportunity clause of this solicitation, the clause originally contained in Section 310 of Executive Order No. 10925, or the clause contained in Section 201 of Executive Order No. 11114;

B. It [ ] has, [ ] has not, filed all required compliance reports; and

C. Representations indicating submission of required compliance reports, signed by proposed subcontractors, will be obtained before subcontract awards.

K.011 TYPE OF BUSINESS ORGANIZATION (JUL 1987) (FAR 52.215-6)

The offeror or quoter, by checking the applicable box, represents that--

A. It operates as [ ] a corporation incorporated under the laws of the State of _____, [ ] an individual, [ ] a partnership, [ ] a nonprofit organization, or [ ] a joint venture; or

B. If the offeror or quoter is a foreign entity, it operates as [ ] an individual, [ ] a partnership, [ ] a nonprofit organization, or [ ] a joint venture, or [ ] a corporation, registered for business in _____.
(country)

K.012 AUTHORIZED NEGOTIATORS (APR 1984) (FAR 52.215-11)

The offeror or quoter represents that the following persons are authorized to negotiate on its behalf with the Government in connection with this request for proposals or quotations: [list names, titles, and telephone numbers of the authorized negotiators].

_____

_____

_____

_____

K.013 PLACE OF PERFORMANCE (APR 1984) (FAR 52.215-20)

A. The offeror or quoter, in the performance of any contract resulting from this solicitation, [ ] intends, [ ] does not intend (check applicable block) to use one or more plants or facilities located at a different address from the address of the offeror or quoter as indicated in this proposal or quotation.

B. If the offeror or quoter checks "intends" in paragraph A. above, it shall insert in the spaces provided below the required information:

Place of Performance (Street Address, City, County, State, Zip Code)	Name and Address of Owner and Operator of the Plant or Facility if Other Than Offeror or Quoter

K.018 REQUIREMENT FOR CERTIFICATE OF PROCUREMENT INTEGRITY (SEP 1995) (FAR 52.203-8, ALTERNATE I) (OTHER THAN SEALED BIDDING)

A. Definitions. The definitions at FAR 3.104-4 are hereby incorporated in this provision.

B. Certifications. As required in paragraph C. of this provision, the officer or employee responsible for this offer shall execute the following certification:

CERTIFICATE OF PROCUREMENT INTEGRITY

1. I, _____ [Name of certifier], am the officer or employee responsible for the preparation of this offer and hereby certify that, to the best of my knowledge and belief, with the exception of any information described in this certificate, I have no information concerning a violation or possible violation of subsection 27(a), (b), (d), or (f) of the Office of Federal Procurement Policy Act, as amended(1) (41 U.S.C. 423), (hereinafter referred to as "the Act"), as implemented in the FAR, occurring during the conduct of this procurement _____ (solicitation number).

2. As required by subsection 27(e)(1)(B) of the Act, I further certify that, to the best of my knowledge and belief, each officer, employee, agent, representative, and consultant of _____ [Name of Offeror] who has participated personally and substantially in the preparation or submission of this offer has certified that he or she is familiar with, and will comply with, the requirements of subsection 27(a) of the Act, as implemented in the FAR, and will report immediately to me any information concerning a violation or possible violation subsections 27(a), (b), (d), or (f) of the Act, as implemented in the FAR, pertaining to this procurement.

3. Violations or possible violations: (Continue on plain bond paper if necessary and label Certificate of Procurement Integrity (Continuation Sheet), ENTER NONE IF NONE EXIST.)

_____
_____
_____
_____

4. I agree that, if awarded a contract under this solicitation, the certifications required by subsection 27(e)(1)(B) of the Act shall be maintained in accordance with paragraph F. of this provision.

Signature of the officer or employee responsible for the offer and date _____.

Typed name of the officer or employee responsible for the offer _____.

THIS CERTIFICATION CONCERNS A MATTER WITHIN THE JURISDICTION OF AN AGENCY OF THE UNITED STATES AND THE MAKING OF A FALSE, FICTITIOUS, OR FRAUDULENT CERTIFICATION MAY RENDER THE MAKER SUBJECT TO PROSECUTION UNDER TITLE 18, UNITED STATES CODE, SECTION 1001.

(End of certification)

(1)Subsections 27(a), (b), and (d) are effective on December 1, 1990. Subsection 27(f) is effective on June 1, 1991.

C. For procurements, including contract modifications, in excess of $100,000 made using procedures other than sealed bidding, the signed certifications shall be submitted by the successful Offeror to the Contracting Officer within the time period specified by the Contracting Officer when requesting the certificates except as provided in subparagraphs C.1. through C.5. of this clause. In no event shall the certificate be submitted subsequent to award of a contract or execution of a contract modification:

1. For letter contracts, other unpriced contracts, or unpriced contract modifications, whether or not the unpriced contract or modification contains a maximum or not to exceed price, the signed certifications shall be submitted prior to the award of the letter contract, unpriced contract, or unpriced contract modification, and prior to the definitization of the letter contract or the establishment of the price of the unpriced contract or unpriced contract modification. The second certification shall apply only to the period between award of the letter contract and execution of the document definitizing the letter contract, or award of the unpriced contract or unpriced contract modification and execution of the document establishing the definitive price of such unpriced contract or unpriced contract modification.

2. For basic ordering agreements, prior to the execution of a priced order; prior to the execution of an unpriced order, whether or not the unpriced order contains a maximum or not to exceed price; and, prior to establishing the price of an unpriced order. The second certificate to be submitted for unpriced orders shall apply only to the period between award of the unpriced order and execution of the document establishing the definitive price for such order.

3. A certificate is not required for indefinite delivery contracts (see Subpart 16.5) unless the total estimated value of all orders eventually to be placed under the contract is expected to exceed $100,000.

4. For contracts and contract modifications which include options, a certificate is required when the aggregate value of the contract or contract modification and all options (see 3.104-4(e)) exceeds $100,000.

5. For purposes of contracts entered into under section 8(a) of the SBA, the business entity with whom the SBA contracts, and not the SBA, shall be required to comply with the certification requirements of subsection 27(e). The SBA shall obtain the signed certificate from the business entity and forward the certificate to the Contracting Officer prior to the award of a contract to the SBA.

6. Failure of an Offeror to submit the signed certificate within the time prescribed by the Contracting Officer shall cause the offer to be rejected.

D. Pursuant to FAR 3.104-9(d), the Offeror may be requested to execute additional certifications at the request of the Government. Failure of an Offeror to submit the additional certifications shall cause its offer to be rejected.

E. A certification containing a disclosure of a violation or possible violation will not necessarily result in the withholding of award under this solicitation. However, the Government, after evaluation of the disclosure, may cancel this procurement or take any other appropriate actions in the interests of the Government, such as disqualification of the Offeror.

F. In making the certification in subparagraph 2. of the certificate, the officer or employee of the competing contractor responsible for the offer may rely upon a one-time certification from each individual required to submit a certification to the competing contractor, supplemented by periodic training. These certifications shall be obtained at the earliest possible date after an individual required to certify begins employment or association with the contractor. If a contractor decides to rely on a certification executed prior to the suspension of section 27 (i.e., prior to December 1, 1989), the contractor shall ensure that an individual who has so certified is notified that section 27 has been reinstated. These certifications shall be maintained by the contractor for 6 years from the date a certifying employee's employment with the company ends or, for an agent, representative, or consultant, 6 years from the date such individual ceases to act on behalf of the contractor.

G. Certifications under paragraphs B. and D. of this provision are material representations of fact upon which reliance will be placed in awarding a contract.

K.019 CERTIFICATION AND DISCLOSURE REGARDING PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (APR 1991) (FAR 52.203-11)

A. The definitions and prohibitions contained in the clause, at FAR 52.203-12, Limitation on Payments to Influence Certain Federal Transactions, included in this solicitation, are hereby incorporated by reference in paragraph B. of this certification.

B. The offeror, by signing its offer, hereby certifies to the best of his or her knowledge and belief that on or after December 23, 1989--

1. No Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress on his or her behalf in connection with the awarding of a contract resulting from this solicitation.

2. If any funds other than Federal appropriated funds (including profit or fee received under a covered Federal transaction) have been paid, or will be paid, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress on his or her behalf in connection with this solicitation, the offeror shall complete and submit, with its offer, OMB standard form LLL, Disclosure of Lobbying Activities, to the Contracting Officer, and

3. He or she will include the language of this certification in all subcontract awards at any tier and require that all recipients of subcontract awards in excess of $100,000 shall certify and disclose accordingly.

C. Submission of this certification and disclosure is a prerequisite for making or entering into this contract imposed by section 1352 title 31, United States Code. Any person who makes an expenditure prohibited under this provision or who fails to file or amend the disclosure form to be filed or amended by this provision, shall be subject to a civil penalty of not less than $10,000, and not more than $100,000, for each such failure.

K.029 AFFIRMATIVE ACTION COMPLIANCE (APR 1984) (FAR 52.222-25)

The offeror represents that (a) it [ ] has developed and has on file, [ ] has not developed and does not have on file, at each establishment, affirmative action programs required by the rules and regulations of the Secretary of Labor (41 CFR 60-1 and 60-2), or (b) it [ ] has not previously had contracts subject to the written affirmative action programs requirements of the rules and regulations of the Secretary of Labor.

K.031 CLEAN AIR AND WATER CERTIFICATION (APR 1984) (FAR 52.223-1)

The Offeror certifies that--

A. Any facility to be used in the performance of this proposed contract is [ ], is not [ ] listed on the Environmental Protection Agency List of Violating Facilities;

B. The Offeror will immediately notify the Contracting Officer, before award, of the receipt of any communication from the Administrator, or a designee, of the Environmental Protection Agency, indicating that any facility that the Offeror proposes to use for the performance of the contract is under consideration to be listed on the EPA List of Violating Facilities; and

C. The Offeror will include a certification substantially the same as this certification, including this paragraph C., in every nonexempt subcontract.

K.033 CERTIFICATION REGARDING A DRUG-FREE WORKPLACE (JUL 1995) (FAR 52.223-5)

A. Definitions. "Controlled substance" means a controlled substance in schedules I through V or section 202 of the Controlled Substances Act (21 U.S.C. 812) and as further defined in regulation at 21 CFR 1308.11-1308.15.

"Conviction" means a finding of guilt (including a plea of nolo contendere) or imposition of sentence, or both, by any judicial body charged with the responsibility to determine violations of the Federal or State criminal drug statutes.

"Criminal drug statute" means a Federal or non-Federal criminal statute involving the manufacture, distribution, dispensing, possession or use of any controlled substance.

"Drug-free workplace" means the site(s) for the performance of work done by the contractor in connection with a specific contract at which employees of the contractor are prohibited from engaging in the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance.

"Employee" means an employee of a contractor directly engaged in the performance of work under a Government contract.

"Directly engaged" is defined to include all direct cost employees and any other contractor employee who has other than a minimal impact or involvement in contract performance.

"Individual" means an offeror/contractor that has no more than one employee including the offeror/contractor.

B. By submission of its offer, the offeror, if other than an individual, who is making an offer that equals or exceeds $25,000, certifies and agrees, that with respect to all employees of the offeror to be employed under a contract resulting from this solicitation, it will--no later than 30 calendar days after contract award (unless a longer period is agreed to in writing), for contracts of 30 calendar days or more performance duration; or as soon as possible for contracts of less than 30 calendar days performance duration, but in any case, by a date prior to when performance is expected to be completed--

1. Publish a statement notifying such employees that the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance is prohibited in the Contractor's workplace and specifying the actions that will be taken against employees for violations of such prohibition;

2. Establish an ongoing a drug-free awareness program to inform such employees about--

   (a) The dangers of drug abuse in the workplace;

   (b) The Contractor's policy of maintaining a drug-free workplace;

   (c) Any available drug counseling, rehabilitation, and employee assistance programs; and

   (d) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace;

3. Provide all employees engaged in performance of the contract with a copy of the statement required by subparagraph B.1. of this provision;

4. Notify such employees in writing in the statement required by subparagraph B.1. of this provision that, as a condition of continued employment on the contract resulting from this solicitation, the employee will--

   (a) Abide by the terms of the statement; and

   (b) Notify the employer in writing of the employee's conviction under a criminal drug statute for a violation occurring in the workplace no later than five (5) calendar days after such conviction;

5. Notify the Contracting Officer in writing within 10 calendar days after receiving notice under subdivision B.4.(b) of this provision, from an employee or otherwise receiving actual notice of such conviction. The notice shall include the position title of the employee; and

6. Within 30 calendar days after receiving notice under subdivision B.4.(b) of this provision of a conviction, take one of the following actions with respect to any employee who is convicted of a drug abuse violation occurring in the workplace:

   (a) Take appropriate personnel action against such employee, up to and including termination; or

(b) Require such employee to satisfactorily participate in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or local health, law enforcement, or other appropriate agency.

7. Make a good faith effort to maintain a drug-free workplace through implementation of subparagraphs B.1. through B.6. of this provision.

C. By submission of its offer, the offeror, if an individual who is making an offer of any dollar value, certifies and agrees that the offeror will not engage in the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance in the performance of the contract resulting from this solicitation.

D. Failure of the offeror to provide the certification required by paragraph B. or C. of this provision, renders the offeror unqualified and ineligible for award. (See FAR 9.104-1(g) and 19.602-1(a)(2)(i).)

E. In addition to other remedies available to the Government, the certification in paragraphs B. or C. of this provision concerns a matter within the jurisdiction of an agency of the United States and the making of a false, fictitious, or fraudulent certification may render the maker subject to prosecution under Title 18, United States Code, Section 1001.

K.039 REPRESENTATION OF LIMITED RIGHTS DATA AND RESTRICTED COMPUTER SOFTWARE (JUN 1987) (FAR 52.227-15)

A. This solicitation sets forth the work to be performed if a contract award results, and the Government's known delivery requirements for data (as defined in FAR 27.401). Any resulting contract may also provide the Government the option to order additional data under the Additional Data Requirements clause at 52.227-16 of the FAR, if included in the contract. Any data delivered under the resulting contract will be subject to the Rights in Data--General clause at 52.227-14 that is to be included in this contract. Under the latter clause, a contractor may withhold from delivery data that qualify as limited rights data or restricted computer software, and deliver form, fit, and function data in lieu thereof. The latter clause also may be used with its Alternates II and/or III to obtain delivery of limited rights data or restricted computer software, marked with limited rights or restricted rights notices, as appropriate. In addition, use of Alternate V with this latter clause provides the Government the right to inspect such data at the Contractor's facility.

B. As an aid in determining the Government's need to include any of the aforementioned Alternates in the clause at 52.227-14, Rights in Data--General, the offeror's response to this solicitation shall, to the extent feasible, complete the representation in paragraph B. of this provision to either state that none of the data qualify as limited rights data or restricted computer software, or identify which of the data qualifies as limited rights data or restricted computer software. Any identification of limited rights data or restricted computer software in the offeror's response is not determinative of the status of such data should a contract be awarded to the offeror.

REPRESENTATION CONCERNING DATA RIGHTS

Offeror has reviewed the requirements for the delivery of data or software and states (offeror check appropriate block)--

[ ] None of the data proposed for fulfilling such requirements qualifies as limited rights data or restricted computer software.

[ ] Data proposed for fulfilling such requirements qualify as limited rights data or restricted computer software and are identified as

_____

_____

_____

_____

NOTE: "Limited rights data" and "Restricted computer software" are defined in the contract clause entitled "Rights in Data--General."

K.040 TECHNICAL DATA CERTIFICATION (APR 1984) (DEAR 952.227-80)

A. The offeror certifies that it has not delivered or is not obligated to deliver to the Government under any contract or subcontract the same or substantially the same technical data included in its offer, except as set forth below:

( ) None.

( ) Contract No. (and Subcontract No., if applicable)

Agency name and place of delivery

B. The work to be performed and the known requirements for technical data as set forth in the solicitation have been reviewed. To the best of my knowledge:

( ) There will be no technical data withheld from delivery as being proprietary data.

( ) The technical data listed on page ____ of the proposal will likely be used in conjunction with the performance of work under the contract and is represented as being proprietary data to be protected from unauthorized use and disclosure and therefore to be withheld from delivery in a report not having a restrictive legend.

K.041 ROYALTY PAYMENTS (APR 1984) (DEAR 952.227-81)

In order that DOE may be informed regarding royalty payments to be made by a contractor in connection with any acquisition, construction, or operation where the amount of the royalty payment is reflected in the contract price, or is to be reimbursed by the Government, check one of the following:

( ) The Contract price includes no amount representing the payment of royalty by the offeror directly to others in connection with the performance of the contract.

( ) The contract price includes an amount for royalty payment expected to be made in connection with the proposed award. The Offeror shall set forth below: (1) the amount of each payment, (2) the names of the licensor, (3) either the patent numbers involved or such other information as will permit identification of the patents and patent applications and the basis on which royalties will be paid.

K.042 COST ACCOUNTING STANDARDS NOTICES AND CERTIFICATION (NOV 1993) (FAR 52.230-1)

NOTE: This notice does not apply to small businesses or foreign governments.

This notice is in three parts, identified by Roman numerals I through III.

Offerors shall examine each part and provide the requested information in order to determine Cost Accounting Standards (CAS) requirements applicable to any resultant contract.

I. DISCLOSURE STATEMENT -- COST ACCOUNTING PRACTICES AND CERTIFICATION

A. Any contract in excess of $500,000 resulting from this solicitation, except contracts in which the price negotiated is based on (1) established catalog or market prices of commercial items sold in substantial quantities to the general public, or (2) prices set by law or regulation, will be subject to the requirements of 48 CFR, Parts 9903 and 9904, except for those contracts which are exempt as specified in 48 CFR, Subpart 9903.201-1.

B. Any offeror submitting a proposal which, if accepted, will result in a contract subject to the requirements of 48 CFR, Parts 9903 and 9904 must, as a condition of contracting, submit a Disclosure Statement as required by 48 CFR, Subpart 9903.202. The Disclosure Statement must be submitted as a part of the offeror's proposal under this solicitation unless the offeror has already submitted a Disclosure Statement disclosing the practices used in connection with the pricing of this proposal. If an applicable Disclosure Statement has already been submitted, the offeror may satisfy the requirement for submission by providing the information requested in paragraph C. of Part I of this provision.

CAUTION: In the absence of specific regulations or agreement, a practice disclosed in a Disclosure Statement shall not, by virtue of such disclosure, be deemed to be a proper, approved, or agreed-to practice for pricing proposals or accumulating and reporting contract performance cost data.

C. Check the appropriate box below:

[ ] 1. Certificate of Concurrent Submission of Disclosure Statement.

The offeror hereby certifies that, as a part of the offer, copies of the Disclosure Statement have been submitted as follows: (i) original and one copy to the cognizant Administrative Contracting Officer (ACO), and (ii) one copy to the cognizant contract auditor.

(Disclosure must be on Form Number CASB-DS-1. Forms may be obtained from the cognizant ACO or from the loose leaf version of the Federal Acquisition Regulation.)

Date of Disclosure Statement: _____
Name and Address of Cognizant ACO where filed: _____

The offeror further certifies that practices used in estimating costs in pricing this proposal are consistent with the cost accounting practices disclosed in the Disclosure Statement.

[ ] 2. Certificate of Previously Submitted Disclosure Statement.

The offeror hereby certifies that Disclosure Statement was filed as follows:

Date of Disclosure Statement: _____
Name and Address of Cognizant ACO where filed: _____

The offeror further certifies that practices used in estimating costs in pricing this proposal are consistent with the cost accounting practices disclosed in the applicable disclosure statement.

[ ] 3. Certificate of Monetary Exemption.

The offeror hereby certifies that the offeror, together with all divisions, subsidiaries, and affiliates under common control, did not receive net awards of negotiated prime contracts and subcontracts subject to CAS totaling more than $25 million (of which at least one award exceeded $1 million) in the cost accounting period immediately preceding the period in which this proposal was submitted. The offeror further certifies that if such status changes before an award resulting from this proposal, the offeror will advise the Contracting Officer immediately.

[ ] 4. Certificate of Interim Exemption.

The offeror hereby certifies that (i) the offeror first exceeded the monetary exemption for disclosure, as defined in 3. of this subsection, in the cost accounting period immediately preceding the period in which this offer was submitted and (ii) in accordance with 48 CFR, Subpart 9903.202-1, the offeror is not yet required to submit a Disclosure Statement. The offeror further certifies that if an award resulting from this proposal has not been made within 90 days after the end of that period, the offeror will immediately submit a revised certificate to the Contracting Officer, in the form specified under subparagraph C.1. or C.2. of Part I of this provision, as appropriate to verify submission of a completed Disclosure Statement.

CAUTION: Offerors currently required to disclose because they were awarded a CAS-covered prime contract or subcontract of $10 million or more in the current cost accounting period may not claim this exemption 4. Further, the exemption applies only in connection with proposals submitted before expiration of the 90-day period following the cost accounting period in which the monetary exemption was exceeded.

II. COST ACCOUNTING STANDARDS -- ELIGIBILITY FOR MODIFIED CONTRACT COVERAGE

If the offeror is eligible to use the modified provisions of 48 CFR, Subpart 9903.201-2(b) and elects to do so, the offeror shall indicate by checking the box below. Checking the box below shall mean that the resultant contract is subject to the Disclosure and Consistency of Cost Accounting Practices clause in lieu of the Cost Accounting Standards clause.

[ ] The offeror hereby claims an exemption from the Cost Accounting Standards clause under the provisions of 48 CFR, Subpart 9903.201-2(b) and certifies that the offeror is eligible for use of the Disclosure and Consistency of Cost Accounting Practices clause because (i) during the cost accounting period immediately preceding the period in which this proposal was submitted,

the offeror received less than $25 million in awards of CAS-covered prime contracts and subcontracts, or (ii) the offeror did not receive a single CAS-covered award exceeding $1 million. The offeror further certifies that if such status changes before an award resulting from this proposal, the offeror will advise the Contracting Officer immediately.

CAUTION: An offeror may not claim the above eligibility for modified contract coverage if this proposal is expected to result in the award of a CAS-covered contract of $25 million or more or if, during its current cost accounting period, the offeror has been awarded a single CAS-covered prime contract or subcontract of $25 million or more.

III. ADDITIONAL COST ACCOUNTING STANDARDS APPLICABLE TO EXISTING CONTRACTS

The offeror shall indicate below whether award of the contemplated contract would, in accordance with paragraph A.3. of the Cost Accounting Standards clause, require a change in established cost accounting practices affecting existing contracts and subcontracts.

[ ] YES [ ] NO

K.045 SIGNATURE/CERTIFICATION

By signing below, the bidder/offeror certifies, under penalty of law, that the representations and certifications are accurate, current, and complete. The bidder/offeror further certifies that it will notify the Contracting Officer of any changes to these representations and certifications. The representations and certification made by the bidder/offeror, as contained herein, concern matters within the jurisdiction of an agency of the United States and the making of a false, fictitious, or fraudulent representation or certification may render the maker subject to prosecution under Title 18, United States Code, Section 1001.

Signature of the Officer or Employee Responsible for the Bid/Offer	Date of Execution
Typed Name and Title of the Officer or Employee Responsible for the Bid/Offer	
Name of Organization	
Address of Organization	
SOLICITATION NUMBER	

PART IV -- SECTION L

INSTRUCTIONS, CONDITIONS, AND NOTICES TO OFFERORS OR QUOTERS

L.001 CONTINUOUS NUMBERING (MAY 1985)

Due to automated procedures employed in formulating this document, provisions contained within it may not always be continuously numbered.

L.002 CONTENT OF RESULTING CONTRACT (APR 1984)

Any contract awarded as a result of this PRDA will contain Part I -- The Schedule, Part II -- Contract Clauses, and Part III, Section J -- List of Documents, Exhibits and Other Attachments (excluding those attachments included in this PRDA relating to submission of proposals). Blank areas appearing in these sections, indicated by "**(To Be Determined)**" will be completed after negotiations.

L.003 REQUEST FOR PROPOSAL (PRDA) NUMBER (APR 1984)

DE-RA26-98FT35008

L.005 DATE OF PRDA ISSUANCE (APR 1984)

September 15, 1997

L.006 DOE ISSUING OFFICE (APR 1984)

U. S. Department of Energy
Federal Energy Technology Center
ATTN: Acquisition and Assistance Division
P.O. Box 880
Morgantown, WV 26507-0880

Point of Contact: Raymond R. Jarr
Telephone: (304)285-4088

L.007 TIME, DATE, AND PLACE PROPOSALS ARE DUE (FEB 1987)

Mailed or hand carried proposals shall be marked as follows:

FROM: _____
_____
_____

MAIL TO or HANDCARRY TO:

U.S. Department of Energy
Federal Energy Technology Center - Morgantown Site
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
ATTN: Raymond R. Jarr

SOLICITATION NO. _____
DUE _____
(Time) (Date)

NOTICE TO DOE MAIL ROOM: DO NOT OPEN. THIS IS A PROPOSAL UNDER THE ABOVE IDENTIFIED SOLICITATION.

Shipping containers shall be marked "TO BE OPENED BY ADDRESSEE ONLY."

A. All proposals are due at 3610 Collins Ferry Road, Morgantown, West Virginia, NO LATER THAN 3:00 P.M. local prevailing time on **November 18, 1997**. (CAUTION: See the proposal submission instructions, including the provision describing treatment of late submissions, modifications, and withdrawals of proposals.)

B. If the offeror elects to forward the offer by means other than the U.S. Mail, he assumes the full responsibility of insuring that the offer is received at the place and by the date and time specified in Paragraph A, above. Such proposals must be closed and sealed as if for mailing.

C. It may not be possible to handcarry the package(s) outside of the hours 7:45 a.m. to 4:15 p.m. workdays. Delivery to any other location may result in late receipt of the proposal and is strongly discouraged.

D. Item samples, if required, must be submitted within the time specified for receipt of offers. Unless otherwise specified in the solicitation, these samples shall be (1) submitted at no expense to the Government and (2) returned at the sender's request and expense, unless they are destroyed during preaward testing.

L.009a SMALL AND SMALL DISADVANTAGED BUSINESS SUBCONTRACTING PLAN (APR 1984)

The offeror's attention is directed to the contract clause in Section I entitled "FAR 52.219-9 -- Small, Small Disadvantaged and Women-Owned Small Business Subcontracting Plan." A successful offeror under this solicitation may be required to submit a plan. Instructions for preparation and submission of the plan are included in the clause.

L.011 FAR 52.216-1 -- TYPE OF CONTRACT (APR 1984)

The Government contemplates award of a cost-reimbursement type contract resulting from this solicitation.

L.014 NUMBER OF AWARDS (APR 1984)

It is anticipated that there will be multiple award(s) resulting from this Solicitation. However, the Government reserves the right to make any number of awards, or no award, if considered to be in the Government's best interest to do so.

L.015 AN EQUAL RIGHTS NOTE (APR 1984)

Wherever, in the solicitation or contract "man," "men," or their related pronouns may appear, either as words or as parts of words (and other than with obvious reference to named male individuals), they have been used for literary purposes and are meant in their generic sense (i.e., to include all humankind -- both female and male sexes).

L.016 FAR 52.215-5 -- SOLICITATION DEFINITIONS (JUL 1987)

"Offer" means "proposal" in negotiation.

"Solicitation" means a request for proposals (PRDA) or a request for quotations (RFQ) in negotiation.

"Government" means United States Government.

L.018 INTENTION TO PROPOSE (APR 1984)

Please review this PRDA and complete the information in the Attachment D, Intention to Propose Form, and mail to the address shown by the earliest practical date. It is recommended that the offeror print the form out prior to completion as it is not intended to be an "input" document. This form is located on a separate file on this diskette entitled, "intent.pro" for ease in printing.

L.019 FALSE STATEMENTS (APR 1984)

Proposals must set forth full, accurate, and complete information as required by this solicitation (including attachments). The penalty for making false statements in proposals is prescribed in 18 U.S.C. 1001.

L.020 EXPENSES RELATED TO OFFEROR SUBMISSIONS (APR 1984)

This PRDA does not commit the Government to pay any costs incurred in the submission of any proposal or in making necessary studies

or designs for the preparation thereof or to acquire or contract for any services.

L.021 DEAR 952.233-2 -- SERVICE OF PROTEST (NOV 1988)

A. Protests, as defined in section 33.101 of the Federal Acquisition Regulation, that are filed directly with an agency, and copies of any protests that are filed with the General Accounting Office (GAO), shall be served on the Contracting Officer (addressed as follows) by obtaining written and dated acknowledgment of receipt from:

Director, Acquisition and Assistance Division
U.S. Department of Energy
Federal Energy Technology Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

B. The copy of any protest shall be received in the office designated above within 1 day of filing a protest with the GAO.

C. Another copy of a protest lodged with the General Accounting Office shall be furnished to the following address:

U.S. Department of Energy
Office of Clearance and Support
Office of Procurement and Assistance
1000 Independence Avenue, S.W.
Washington, DC 20585

D. Another copy of a protest lodged with the General Services Administration Board of Contract Appeals shall be furnished to the following address:

U.S. Department of Energy
Assistant General Counsel for
Procurement and Finance (GC-34)
1000 Independence Avenue, S.W.
Washington, DC 20585

L.022a AMENDMENTS OF THE TO SOLICITATION (APR 1984)

The only method by which any term of the PRDA may be modified is by an express, formal amendment to the solicitation generated by the issuing office. No other communication made at any scheduled preproposal conference or subsequent discussions, whether oral or in writing, will modify or supersede the terms of the PRDA. Receipt of an amendment to a solicitation by an offeror must be acknowledged on the SF33 Form. Such acknowledgment must be received prior to the hour and date specified for receipt of offers. Note that amendments will be posted on the FETC Homepage at:

http://www.metc.doe.gov/business/solicita.html.

L.023 COMMITMENT OF PUBLIC FUNDS (APR 1984)

The Contracting Officer is the only individual who can legally commit the Government to the expenditure of public funds in connection with the proposed procurement. Any other commitment, either explicit or implied, is invalid.

L.024a PREPROPOSAL CONFERENCE -- NONE (APR 1984)

A preproposal conference is not contemplated.

L.029 FAR 52.228-6 -- INSURANCE -- IMMUNITY FROM TORT LIABILITY (APR 1984)

If the offeror is partially or totally immune from tort liability to third persons as a State agency or as a charitable institution, and includes in its offer a representation to that effect, the clause at 52.228-7, Insurance -- Liability to Third Persons, will be included in the contract:

A. With its Alternate I, if the offeror represents that it is partially immune from tort liability to third persons as a State agency or as a charitable institution; or

B. With its Alternate II, if the offeror represents that it is totally immune from tort liability to third persons as a State agency or as a charitable institution.

L.030 DEAR 952.227-84 --RIGHT TO REQUEST PATENT WAIVER (APR 1984)

Offerors and prospective contractors, in accordance with applicable statutes and the Department of Energy Acquisition Regulation, have the right to request, in advance of or within 30 days after the effective date of contracting, a waiver of all or any part of the rights of the United States in subject inventions. Small business firms and nonprofit organizations normally will receive the Patent Rights clause of 952.227-71 which permits the contractor to retain title of subject inventions. Therefore small business firms and nonprofit organizations normally need not request a waiver.

L.031 CLASSIFIED MATERIAL -- NONE (APR 1984)

Performance under the proposed contract is not anticipated to involve access to classified material.

L.033 NOTICE OF LABOR PROVISIONS (APR 1984)

A. LISTING OF EMPLOYMENT OPENING (APR 1984)

Offerors should note that this solicitation includes, in the model contract, clauses requiring the listing of employment openings with the local office of the Federal-State

employment service system where a contract award is for $10,000 or more. (See clauses "Affirmative Action for Special Disabled and Vietnam Era Veterans" and "Affirmative Action for Handicapped Workers").

B. INFORMATION FROM DEPARTMENT OF LABOR (APR 1984)

General information regarding the requirements of the Walsh-Healey Public Contracts Act (41 U.S.C. 35-45), the Contract Work Hours Standards Act (40 U.S.C. 327-333), and the Service Contract Act of 1965 (41 U.S.C. 351-358) may be obtained from the Department of Labor, Washington, D.C., 20310, or from any regional office of that agency. Requests for information should include the PRDA number, the name and address of the issuing agency, and a description of the supplies or services.

L.034 RESPONSIBLE PROSPECTIVE CONTRACTORS (APR 1984)

A. The general and additional minimum standards for responsible prospective contractors set forth at 48 CFR 9.1 and 48 CFR 909.104-70 apply.

B. DOE may conduct preaward surveys in accordance with 48 CFR 9.106 and may solicit from available sources, relevant information concerning the offeror's record of past performance, and use such information in making determinations of prospective offeror responsibility.

L.035 DISCUSSIONS WITH OFFERORS (APR 1984)

The Contracting Officer may conduct written or oral discussions with any or all of the offerors. Offerors will be notified of the date, time, and place for any such oral discussions. Any such discussions will be conducted in accordance with DOE acquisition policies and procedures.

L.036 INFORMATION OF AWARD (APR 1984)

Written notice to unsuccessful offerors and contract award information will be promptly released in accordance with DOE regulations applicable to negotiated acquisitions.

L.037 DISPOSITION OF PROPOSALS (APR 1984)

Proposals will not be returned (except for timely withdrawals).

L.038 DISPOSITION OF PRDA DOCUMENTS (APR 1984)

Drawings, specifications, and other documents supplied with the PRDA may be retained by the offeror (unless there is a requirement for a document to be completed and returned as a part of the offer).

L.039a ALTERNATE PROPOSAL INFORMATION (NONE) (APR 1984)

Alternate proposals are not solicited, are not desired, and shall not be evaluated.

L.051 FAR 52.215-7 -- UNNECESSARILY ELABORATE PROPOSALS OR QUOTATIONS (APR 1984)

Unnecessarily elaborate brochures or other presentations beyond those sufficient to present a complete and effective response to this solicitation are not desired and may be construed as an indication of the offeror's or quoter's lack of cost consciousness. Elaborate art work, expensive paper and bindings, and expensive visual and other presentation aids are neither necessary nor wanted.

L.052 FAR 52.215-9 -- SUBMISSION OF OFFERS (MAR 1997)

A. Offers and modifications thereof shall be submitted in sealed envelopes or packages (1) addressed to the office specified in the solicitation, and (2) showing the time and date specified for receipt, the solicitation number, and the name and address of the offeror.

B. Offerors using commercial carrier services shall ensure that the proposal is addressed and marked on the outermost envelope or wrapper as prescribed in subparagraphs A.(1) and (2) of this provision when delivered to the office specified in the solicitation.

C. Telegraphic offers will not be considered unless authorized by the solicitation; however, offers may be modified by written or telegraphic notice.

D. Facsimile offers, modifications or withdrawals will not be considered unless authorized by the solicitation.

E. Offers submitted by electronic commerce shall be considered only if the electronic commerce method was specifically stipulated or permitted by the solicitation.

F. Item samples, if required, must be submitted within the time specified for receipt of offers. Unless otherwise specified in the solicitation, these samples shall be (1) submitted at no expense to the Government, and (2) returned at the sender's request and expense, unless they are destroyed during preaward testing.

L.053 FAR 52.215-10 -- LATE SUBMISSIONS, MODIFICATIONS, AND WITHDRAWALS OF PROPOSALS (JUN 1997)

A. Any proposal received at the office designated in the solicitation after the exact time specified for receipt of offers will not be considered unless it is received before award is made and--

1. It was sent by registered or certified mail not later than the fifth calendar day before the date specified for receipt of offers (e.g., an offer submitted in response to a solicitation requiring receipt of offers by the 20th of the month must have been mailed by the 15th);

2. It was sent by mail (or telegram or facsimile, if authorized) or hand-carried (including delivery by a common carrier) or if it is determined by the Government that the late receipt was due primarily to Government mishandling after receipt at the Government installation;

3. It was sent by U.S. Postal Service Express Mail Next Day Service-Post Office to Addressee, not later than 5:00 p.m. at the place of mailing two working days prior to the date specified for receipt of proposals. The term "working days" excludes weekends and U.S. Federal holidays;

4. It was transmitted through an electronic commerce method authorized by the solicitation and was received at the initial point of entry to the Government infrastructure not later than 5:00 p.m. one working day prior to the date specified for receipt of proposals;

5. There is acceptable evidence to establish that it was received at the activity designated for receipt of offers and was under the Government's control prior to the time set for receipt of offers, and the Contracting Officer determines that accepting the late offer would not unduly delay the procurement; or

6. It is the only proposal received.

B. Any modification of a proposal or quotation, including a modification resulting from the Contracting Officer's request for "best and final" offer, is subject to the same conditions as in subparagraphs A.1. through A.5. of this provision.

C. The only acceptable evidence to establish the date of mailing of a late proposal or modification sent either by U.S. Postal Service registered or certified mail is the U.S. or Canadian Postal Service postmark both on the envelope or wrapper and on the original receipt from the U.S. or Canadian Postal Service. Both postmarks must show a legible date or the proposal, quotation, or modification shall be processed as if mailed late. "Postmark" means a printed, stamped, or otherwise placed impression (exclusive of a postage meter machine impression) that is readily identifiable without further action as having been supplied and affixed by employees of the U.S. or Canadian Postal Service on the date of mailing. Therefore, offerors or quoters should request the postal clerk to place a legible hand cancellation bull's eye postmark on both the receipt and the envelope or wrapper.

D. Acceptable evidence to establish the time of receipt at the Government installation includes the time/date stamp of that installation on the proposal wrapper, other documentary evidence of receipt maintained by the installation, or oral testimony or statements of Government personnel.

E. The only acceptable evidence to establish the date of mailing of a late offer, modification, or withdrawal sent by Express Mail Next Day Service-Post Office to Addressee is the date entered by the post office receiving clerk on the "Express Mail Next Day Service-Post Office to Addressee" label and the postmark on both the envelope or wrapper and on the original receipt from the U.S. Postal Service. "Postmark" has the same meaning as defined in paragraph D. of this provision, excluding postmarks of the Canadian Postal Service. Therefore, offerors or quoters should request the postal clerk to place a legible hand cancellation bull's eye postmark on both the receipt and the envelope or wrapper.

F. Notwithstanding paragraph A. of this provision, a late modification of an otherwise successful proposal that makes its terms more favorable to the Government will be considered at any time it is received and may be accepted.

G. Proposals may be withdrawn by written notice or telegram (including mailgram) received at any time before award. If the solicitation authorizes facsimile proposals, proposals may be withdrawn via facsimile received at any time before award, subject to the conditions specified in the provision entitled "Facsimile Proposals." Proposals may be withdrawn in person or by an offeror or an authorized representative, if the representative's identity is made known and the representative signs a receipt for the proposal before award.

H. If an emergency or unanticipated event interrupts normal Government processes so that proposals cannot be received at the office designated for receipt of proposals by the exact time specified in the solicitation, and urgent Government requirements preclude amendment of the solicitation or other notice of an extension of the closing date, the time specified for receipt of proposals will be deemed to be extended to the same time of day specified in the solicitation on the first work day on which normal Government processes resume. If no time is specified in the solicitation, the time for receipt is 4:30 p.m., local time, for the designated Government office.

L.054 FAR 52.215-12 -- RESTRICTION ON DISCLOSURE AND USE OF DATA (APR 1984)

Offerors or quoters who include in their proposals or quotations data that they do not want disclosed to the public for any purpose or used by the Government except for evaluation purposes, shall--

A. Mark the title page with the following legend:

"This proposal or quotation includes data that shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed--in whole or in part--for any purpose other than to evaluate this proposal or quotation. If, however, a contract is awarded to this offeror or quoter as a result of--or in connection with--the submission of this data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the resulting contract. This restriction does not limit the Government's right to use information contained in this data if it is obtained from another source without restriction. The data subject to this restriction are contained in sheets _____ (insert numbers or other identification of sheets)"; and

B. Mark each sheet of data it wishes to restrict with the following legend:

"Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal or quotation."

L.055 FAR 52.215-14 -- EXPLANATION TO PROSPECTIVE OFFERORS (APR 1984)

Any prospective offeror desiring an explanation or interpretation of the solicitation, drawings, specifications, etc., must request it in writing soon enough to allow a reply to reach all prospective offerors before the submission of their offers. Oral explanations or instructions given before the award of the contract will not be binding. Any information given to a prospective offeror concerning a solicitation will be furnished promptly to all other prospective offerors as an amendment of the solicitation, if that information is necessary in submitting offers or if the lack of it would be prejudicial to any other prospective offerors.

L.057 FAR 52.215-16 CONTRACT AWARD (OCT 1995)

A. The Government will award a contract resulting from this solicitation to the responsible offeror whose offer conforming to the solicitation will be most advantageous to the Government, cost or price and other factors, specified elsewhere in this solicitation, considered.

B. The Government may (1) reject any or all offers if such action is in the public interest, (2) accept other than the lowest offer, and (3) waive informalities and minor irregularities in offers received.

C. The Government intends to evaluate proposals and award a contract after conducting written or oral discussions with all responsible offerors whose proposals have been

determined to be within the competitive range. However, each initial offer should contain the offeror's best terms from a cost or price and technical standpoint.

D. The Government may accept any item or group of items of an offer, unless the offeror qualifies the offer by specific limitations. Unless otherwise provided in the Schedule, offers may be submitted for quantities less than those specified. The Government reserves the right to make an award on any item for a quantity less than the quantity offered, at the unit cost or prices offered, unless the offeror specifies otherwise in the offer.

E. A written award or acceptance of offer mailed or otherwise furnished to the successful offeror within the time for acceptance specified in the offer shall result in a binding contract without further action by either party. Before the offer's specified expiration time, the Government may accept an offer (or part of an offer, as provided in paragraph D. above), whether or not there are negotiations after its receipt, unless a written notice of withdrawal is received before award. Negotiations conducted after receipt of an offer do not constitute a rejection or counteroffer by the Government.

F. Neither financial data submitted with an offer, nor representations concerning facilities or financing, will form a part of the resulting contract. However, if the resulting contract contains a clause providing for price reduction for defective cost or pricing data, the contract price will be subject to reduction if cost or pricing data furnished is incomplete, inaccurate, or not current.

G. The Government may determine that an offer is unacceptable if the prices proposed are materially unbalanced between line items or subline items. An offer is materially unbalanced when it is based on prices significantly less than cost for some work and prices which are significantly overstated in relation to cost for other work, and if there is a reasonable doubt that the offer will result in the lowest overall cost to the Government, even though it may be the low evaluated offer, or it is so unbalanced as to be tantamount to allowing an advance payment.

H. The Government may disclose the following information in post-award debriefings to other offerors: (1) the overall evaluated cost or price and technical rating of the successful offeror; (2) the overall ranking of all offerors, when any ranking was developed by the agency during source selection; (3) a summary of the rationale for award; and (4) for acquisitions of commercial end items, the make and model of the item to be delivered by the successful offeror.

L.065 FAR 52.222-24 -- PREAWARD ON-SITE EQUAL OPPORTUNITY COMPLIANCE REVIEW (APR 1984)

An award in the amount of $1 million or more will not be made under this solicitation unless the offeror and each of its known first-tier subcontractors (to whom it intends to award a subcontract of $1 million or more) are found, on the basis of a compliance review, to be able to comply with the provisions of the Equal Opportunity clause of this solicitation.

L.066 FAR 52.215-13 -- PREPARATION OF OFFERS (APR 1984)

A. Offerors are expected to examine the drawings, specifications, Schedule, and all instructions. Failure to do so will be at the offeror's risk.

B. Each offeror shall furnish the information required by the solicitation. The offeror shall sign the offer and print or type its name on the Schedule and each continuation sheet on which it makes an entry. Erasures or other changes must be initialed by the person signing the offer. Offers signed by an agent shall be accompanied by evidence of that agent's authority, unless that evidence has been previously furnished to the issuing office.

C. For each item offered, offerors shall (1) show the unit price/ cost, including, unless otherwise specified, packaging, packing, and preservation and (2) enter the extended price/cost for the quantity of each item offered in the "Amount" column of the Schedule. In case of discrepancy between a unit price/cost and an extended price/cost, the unit price/cost will be presumed to be correct, subject, however, to correction to the same extent and in the same manner as any other mistake.

D. Offers for supplies or services other than those specified will not be considered unless authorized by the solicitation.

E. Offerors must state a definite time for delivery of supplies or for performance of services, unless otherwise specified in the solicitation.

F. Time, if stated as a number of days, will include Saturdays, Sundays, and holidays.

L.067a(S) PROPOSAL PREPARATION INSTRUCTIONS -- GENERAL (APR 1984)

A. General. To aid in evaluation, proposals shall be clearly and concisely written as well as being neat, indexed (cross-indexed as appropriate), and logically assembled. All pages of each part shall be appropriately numbered, and identified with the name of the offeror, the date, and the PRDA number to the extent practicable.

B. Overall Arrangement of Proposal.

1. The overall proposal shall consist of three (3) physically separate volumes, individually entitled as stated below. The required number of each proposal volume is shown below.

Proposal Volume -- Title	Original (Copy #1)	Total Copies Required
Volume I -- Offer and Other Documents	1	1
Volume II -- Technical Proposal	1	4
Volume III -- Cost Proposal	1	3

2. Originals.

Originals of all documents requiring signature by the offeror shall be provided. Use of reproductions of signed originals is authorized in all other copies of the proposal.

3. The offeror shall not provide proposal information in three ring binders.

L.068(S) PROPOSAL PREPARATION INSTRUCTIONS -- VOLUME I, OFFER AND OTHER DOCUMENTS (APR 1984)

A. General.

Volume I, Offer and Other Documents, consists of the actual offer to enter into a contract to perform the desired work. Although it incorporates them by reference, it does not physically include the other volumes.

B. Format and Content.

Volume I, Offer and Other Documents, shall include the following (in the order listed):

1. The SF 33 Form -- Solicitation, Offer and Award (Page 1 of this solicitation)

a. Offerors shall complete Blocks 12, 15A, 15B, 15C, 16, and sign in Block 17; should an amendment(s) be issued, block 14, Acknowledgement of Amendments, shall be completed. Two signed originals shall be provided.

b. The offer Acceptance Period (See Block 12) entered shall not be less than 180 days.

c. Signature Authority. The person signing the SF33 must have the authority to commit the offeror to all of the provisions of the proposal.

2. Offeror Representations and Certifications fully executed.

a. Offeror Representations and Certifications included under Section K are to be fully executed and included in Volume I, Offer and Other Documents. As stated in Section K, should an offeror be selected for further negotiations, he must certify to the certifications referenced.

3. Exceptions and Deviations

The offeror shall identify and explain any exceptions or deviations taken or conditional assumptions made with respect to the model contract, Offeror Representations, Certifications, and other Statement of the offeror form, the requirements of this Section, and other matters included in Volume I -- Offer and Other Documents. The offeror shall summarize each technical, cost, business, or other exceptions taken elsewhere, and provide specific cross references to its full discussion.

Any exceptions taken must contain sufficient amplification and justification to permit evaluation. The benefit to the Government shall be explained for each exception taken. Such exceptions will not, of themselves, automatically cause a proposal to be termed unacceptable. A large number of exceptions, or one or more significant exceptions not providing benefit to the Government, however, may result in rejection of your proposal(s) as unacceptable.

L.069b(S) PROPOSAL PREPARATION INSTRUCTIONS -- VOLUME II, TECHNICAL PROPOSAL(APR1984)

A. General.

1. Volume II -- Technical Proposal consists of the offeror's outline addressing the technical and management aspects of the acquisition, his capabilities and what he will do to satisfy the requirements of the Statement of Work. Since the Technical Proposal will be evaluated to determine such matters as understanding of the work to be performed, technical approach, scientific and technical innovation, impact on greenhouse gas sequestration, and potential for completing the desired work (Part IV -- Section M and Part I -- Section C), it should be specific and complete in every detail.

2. In order that the Technical Proposal may be evaluated strictly on the merit of the material submitted, no

contractual cost information is to be included in the Technical Proposal. Where estimated man-hours will provide clarity, they shall be quoted in man-hour figures only, with no indication as to the cost of these man-hours.

3. The expected project results reflect the problems and objective of the program under consideration; therefore, repeating the scope of work without sufficient elaboration will not be acceptable.

4. The Technical Proposal shall not exceed 50 pages (excluding resumes). For interpretation of page guidelines, the front and back of a single sheet are counted as two pages. The proposed text shall be typed, single spaced, using 12 point type (or equivalent) and printed, unreduced on size 8 1/2-inch by 11-inch paper. Illustrations shall be legible and no longer than 11-inch by 17-inch fold-outs, as appropriate for the subject matter. Each 11-inch by 17-inch fold-out is considered two pages when determining the number of pages. Pages of each volume shall be sequentially numbered with the volume and page numbers on each page. Except as otherwise noted in the PRDA, the page guidelines previously set forth constitute a limitation on the total amount of material that may be submitted for evaluation. No material may be incorporated in any proposal by reference as a means to circumvent the page limitation.

B. Format and Content.

1. Volume II, Technical Proposal. This volume should include the following components

a. Cover Page.

b. Table of Contents.

c. Technical Summary. This short one (1) page section should outline the offeror's proposed general approach for Phases I, II, and III. The summary shall contain one or more of the greenhouse gases of interest and how the offeror plans on completing the proposed Statement of Work, and shall outline the overall technical aspects of the proposed system development effort from project inception to a commercial level of Industry acceptance.

d. Technical Discussion. This section shall contain the major portion of the Technical Proposal for only Phases I and II. It should clearly address each of the Technical Proposal evaluation criteria in Part IV --Section M, and at a minimum cover the elements listed below. It should be presented in as much detail as practical and

include the following aspects for appropriate criteria:

i. SCIENTIFIC/TECHNICAL INNOVATION

The offeror shall clearly describe its proposed "path-breaking," "revolutionary" concept to sequester and recycle greenhouse gases or the direct utilization of greenhouse gases that is beyond evolutionary development currently under consideration and bring the concept to a stage of technical development sufficient to prove validity on an engineering scale. The offeror shall propose new advanced and innovative technology, concepts, methods, or systems that are undeveloped or considered unsuitable for current application.

ii. IMPACT

The offeror shall clearly describe the proposed concept's technical merit and potential impact in terms of applicability to a large number of sites and quantity (tons) of greenhouse gases that would be recovered or sequestered, and the feasibility of the proposed concept for the development of path-breaking, less costly means to addressing greenhouse gas emissions. The offeror shall also describe how scientific knowledge and understanding of the path-breaking technologies would be applied to the reduction of greenhouse gas emissions or the direct utilization of greenhouse gases.

iii. TECHNICAL APPROACH AND UNDERSTANDING OF THE OBJECTIVES

This section shall describe the offeror's technical approach to achieving the objectives of the development of novel, low cost concepts to recover, sequester, or provide for the direct utilizstion of greenhouse gases.

The offeror shall synthesize its technical approach section of the proposal into a Statement of Work (SOW) attachment which provides a precise scope statement followed by sequential tasks descriptions necessary to accomplish the project objectives (See Part III, Section J, Attachment A and A1 for instructions). The SOW attachment shall not exceed 7 pages in length; it will not count toward the 50 page technical proposal limitation. The offeror shall provide a clear description of the work to be performed under each task. The SOW shall be written in active voice using consistent wording and shall contain necessary and sufficient information to estimate the cost of the work. The SOW should include

three phases. Phase I type efforts will involve the technical and preliminary economic assessment of the proposed concept as to the feasibility of the proposed technology. Phase II type efforts will involve small scale engineering or laboratory studies supporting development of the proposed technology concept; and Phase III type efforts will involve scale-up of experimental studies up to pilot-scale, slip-stream, or field tests to verify engineering and process operations and integration. A competitive down selection process shall be included at the conclusion of Phases I and II.

The offeror shall provide a table listing the estimated labor hours and labor categories (e.g., engineering, manufacturing, scientific, technician, analytical, clerical) required for each task. It is not sufficient to merely indicate a certain number of hours; a determination as to why that number of hours is required. In addition, the hours shall be related to the specific tasks to be performed and, as far as possible, shall indicate the job disciplines and classifications (engineering, manufacturing, scientific) under each task. No contractual cost information is to be included in the technical proposal.

The offeror shall detail labor hours and labor categories for any proposed subcontracting or consulting effort for each task. It should also indicate the extent to which the offeror has previously worked with the proposed consultant or subcontractor. No pricing information shall be included in the Technical Proposal. The offeror shall explain the purpose of the subcontract or consulting effort.

A proposed time schedule for completion of work, indicating task start times, and schedule interrelationships shall be included. Key milestone accomplishment times should be clearly established.

The offeror shall describe proposed travel and detail the purpose of the trip, number of trips, the origin and destination, trip duration, and the number of personnel shall be included.

iv. <u>QUALIFICATIONS OF ORGANIZATION AND KEY PERSONNEL</u>

The offeror shall discuss any prior experience in projects that were similar in type, size, and complexity. The offeror shall expound on its experience in the management and execution of

pilot-scale and field tests. The offeror should also outline relevant experience of proposed team members.

The offeror shall discuss the current project organization and its ability to successfully perform the proposed project, including access to technical and financial resources.

The offeror shall describe the structure, function, and individual responsibilities of the proposed project organization. A chart illustrating the proposed project organization shall be provided showing names, position titles, and lines of authority for personnel assigned to the project.

The offeror shall describe the relevant technical and managerial experience of the proposed personnel, including subcontractors and consultants. The offeror shall provide resumes which includes the relevant background and qualifications of each of the key personnel who will be assigned to the project (the resumes will not be included in calculating the 50 page limitation). The offeror shall describe any unique qualifications of the personnel, organization, or teaming arrangement. The offeror shall also discuss the availability of personnel for the project.

v. FACILITIES

The offeror shall furnish a list of materials, parts, and equipment required for the project. The offeror shall discuss the type, quality, and availability of the proposed equipment, materials, and facilities. The offeror shall justify the purchase or lease of facilities, equipment, and materials. This data shall also be related to the tasks under which the equipment is required and the schedule time frame in which such equipment is required. The offeror shall describe any unique features of the equipment and facilities.

e. Statement of Work Attachment.

f. Resumes.

g. Public Abstract. This section shall contain a public abstract of not more that 500 words describing the proposed project, the objective, methodology, sponsoring organization(s), and time frame. Not more than two 8-1/2 by 11-inch diagrams may be included with the abstract. The abstract must provide an overview of the proposed project. This abstract may be released to the public by DOE in whole or in part at any time;

therefore, no proprietary data or confidential business information shall be included.

L.070b(S) PROPOSAL PREPARATION INSTRUCTIONS -- VOLUME III, COST PROPOSAL -- R&D (APR 1984)

A. General.

1. The Cost Proposal, Volume III, consists of the offeror's estimated costs to perform the desired work as set forth in the proposed SOW. Contractual cost information is not to be included in the Technical Proposal, Volume II, or the Offer and Other Documents, Volume I. The SF-1411 and Exhibits thereto are attached to this solicitation. (See Part III -- Section J.)

2. Once the prospective contractor has been selected, the estimated costs submitted with the proposal shall not be subject to increase, except for changes in Certified Cost or Pricing Data submitted with the proposal, unless changes are made in the requirements of the PRDA.

Furthermore, increases shall be considered only in regard to those requirements that are actually affected by the changes (whether they are initiated by the Government, or the offeror), and then only to the extent that such increases will be considered separately, and not as part of a combined overall negotiation of the estimated cost and fee for the proposed contract.

4. Major Subcontracts (Including Intercompany Transfers): For each subcontract requiring Certified Cost and Pricing Data, cost information shall be required and furnished in the same format and level of detail as prescribed for the offeror in this PRDA. Furnish reasons for any differences in the amount proposed by the offeror to the Government for the subcontracted work.

5. Joint Ventures/Teaming Arrangements: If a joint venture or teaming arrangement is proposed, the participants shall clearly identify which cost element(s) pertain to what participant.

6. High-Value Equipment: Offerors are informed that when the use of High Value Equipment (in excess of $10,000) is applied to this acquisition, the Government reserves the right to require the submission of the feasibility of lease versus purchase studies by the successful offeror.

7. Use of ADPE: If the use of automatic data processing equipment (ADPE) is proposed by the offeror, the

Government reserves the right to require the preparation of (a) feasibility and (b) lease versus purchase studies by the successful offeror.

B. Certified Cost or Pricing Data. Offerors may be required to certify (in accordance with Pub. L. 87-653 as implemented by FAR 15.804) that any cost or pricing data submitted is accurate, complete and current. In such an event, the required format for the certification can be found in FAR 15.804-4. The executed certification must be presented to the Contracting Officer after negotiations are concluded and before award can be made. FAR 15.804-7 contains applicable procedures where it is subsequently found that defective cost or pricing data was submitted.

Any offeror required to submit the above certification shall be required (in accordance with FAR 15.804-2) to submit, or arrange for the submission of, accurate, complete, and current cost or pricing data from his prospective subcontractors. This requirement may be waived under the circumstances set forth in FAR 15.804-3.

Notwithstanding the above paragraphs, any successful offeror shall comply with applicable requirements of the "Subcontractor Cost or Pricing Data", or "Subcontractor Cost and Pricing Data -- Modifications" clauses of the awarded contract.

C. Format and Contents.

The cost proposal shall include two sections: Section One - Mandatory Exhibits and Section Two - Additional Information.

A. Preparation of Section One - Mandatory Exhibits:

1. Exhibit A: SF-1411s are mandatory requirements. One fully executed SF-1411 shall be completed for Phases I, II, and III.

a. Supporting cost detail shall be provided for only Phases I and II, as appropriate, on additional pages utilizing the following format:

Cost Element	Task Number				Total
	1	2	3	4	
Direct Labor	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Labor Overhead	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Travel	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Printing/Reproduction	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Freight/Postage	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Expendable Materials	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Subcontracts/Consultants	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Equipment	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Other	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Subtotal	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
General & Administrative	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Total Cost	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Fixed Fee	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx
Total Estimated Cost and Fixed Fee	$xxxxx	$xxxxx	$xxxxx	$xxxxx	$xxxxx

1. Exhibit B - Labor: Direct Labor shall be supported by a matrix identifying labor categories, hours proposed, hourly rate and cost on a per-task and total project basis.

2. Exhibit C - Escalation: This Exhibit shall contain by cost element, the effective annual escalation rate each offeror expects to experience during the performance of this contract.

3. Exhibit D - Indirect Rates: This Exhibit will contain the major base and pool expense groupings by line item and dollar amount. This Exhibit shall be prepared for the offeror's most recently completed Fiscal Year, the current Fiscal Year, and the estimate for the next Fiscal Year. The offeror shall state at the bottom of the exhibit the inclusive dates of their Fiscal Year. The Offeror may substitute a Government approved written indirect rate agreement if such agreement contains rates that cover the period of performance.

4. Exhibit E - Travel/Other Direct Costs/Materials: This Exhibit shall contain itemized listings and justifications for any other direct costs such as travel, freight, materials, etc. **Travel** shall be supported by a matrix identifying number of trips, locations to be visited, number of persons traveling, transportation cost, per diem cost, and total cost. For pricing purposes, offerors should assume that the briefings required under the SOW will be conducted at FETC-Morgantown. **Printing/ Reproduction** cost may be identified as a flat amount on a per-task basis. **Freight/Postage** cost may be identified as a flat rate on a per-task basis. **Expendable Materials** must be supported by identifying the materials to be consumed, the unit cost and the number of units to be used.

5. Exhibit F - Property: This exhibit shall detail the property (equipment) to be purchased or furnished.

Equipment must be supported by identifying the item(s), the unit cost, and the total cost. If your proposal is based on the use of Government furnished property (GFP), provide a list of those items on this exhibit and show how their use increases or decreases the cost of the proposed work, also state how the property is being acquired, from whom and how it will be used during this contract.

6. Exhibit G - Subcontracts: This exhibit shall detail all subcontract and consultant costs.

Subcontracts/Consultants must be supported in the same level of detail as the base contract, on a task-by-task and total basis.

Additional documentation is required by the DOE for subcontracts in excess $25,000:

a. A brief description of the work to be subcontracted.
b. Names and addresses of the subcontractors tentatively selected and basis, i.e., low bidder, delivery schedule, technical competence, etc.
c. The number of quotes solicited and received, i.e. extent of competition.
d. A rating of the subcontractor's competence (fair, good, excellent).
e. Type of contract and estimated cost and fee or profit.
f. Affiliation with offeror, if any.
g. Whether or not subcontractor is a small business concern or a minority business concern.

Consultants: If the offeror proposes the use of named consultants, provide the following:

a. Resume.
b. Details regarding the proposed rate and its reasonability, and justification for selecting the consultant.

Should the offeror be selected by the DOE for further negotiations, additional details for proposed consultant will be requested. These include, but need not be submitted at this time:

b. Details of what cost elements are included in the rate, and what costs would be charged over and above the rate.

c. A signed statement from the consultant that the proposed rate is a "Most Favored Customer Rate," or the reason it was not offered.

d. A rate comparison from the offeror which details that the rate proposed is comparable to the rates of other consultants doing similar types of work.

e. The offeror shall prepare a technical evaluation of the need to employ a consultant, which shall include the consultant's technical ability to perform the desired work, along with a statement to the effect that in-house resources are unavailable for performance of the effort.

f. A signed consulting agreement.

g. An invoice substantiating the proposed rate and confirmation of payment.

B. Preparation of Section Two, Additional Information.

1. Estimating Procedure. Include a discussion of the rationale used in estimating the various cost elements. For effective negotiations, it is essential that there be a clear understanding of:

a. The existing verifiable data;

b. The judgmental factors applied in projecting from known data to the estimate;

c. The contingencies used by the offeror in the proposed costs.

L.080 ORDER OF PRECEDENCE (JUN 1989)

Any inconsistency in this solicitation shall be resolved by giving precedence in the following order: (a) the Schedule (including the Statement of Work); (b) representations and other instructions; (c) contract clauses; (d) other documents, exhibits, and attachments.

L.096 DEAR 952.227-83 -- RIGHTS IN TECHNICAL DATA SOLICITATION INSTRUCTION (APR 1984)

The section of this solicitation which describes the work to be performed also sets forth DOE's known requirements for technical data. The Additional Technical Data Requirements clause, if included in this solicitation, provides the Government with the option to order additional technical data, the requirements for which are not known at the time of contracting. There is, however, a built-in limitation on the kind of technical data which may be required. This limitation provides that the contractor may withhold delivery of proprietary data. Accordingly, it is necessary that your proposal state that the work to be performed and the known requirements for technical data as set forth in the solicitation have been reviewed, and either state that, to the best of your knowledge, no data will be withheld, or submit a list identifying the proprietary data which, to the best of your knowledge, will likely be used in the contract performance and will be withheld.

L.100 ROYALTY INFORMATION (APR 1984)

A. Cost or Charges for Royalties

When the response to this solicitation contains costs or charges for royalties totaling more than $250, the following information shall be included in the response relating to each separate item of royalty or license fee:

1. Name and address of licensor.

2. Date of license agreement.

3. Patent numbers, patent application serial numbers, or other basis on which the royalty is payable.

4. Brief description, including any part or model numbers of each contract item or component on which the royalty is payable.

5. Percentage or dollar rate of royalty per unit.

6. Unit price of contract item.

7. Number of units.

8. Total dollar amount of royalties.

B. Copies of Current Licenses

In addition, if specifically requested by the Contracting Officer before execution of the contact, the offeror shall furnish a copy of the current license agreement and an identification of applicable claims of specific patents.

PART IV -- SECTION M

EVALUATION FACTORS FOR AWARD

M.001a GENERAL (APR 1984)

A. Proposals will be evaluated in accordance with applicable DOE acquisition policies and procedures. Evaluation will be performed to determine the offeror's understanding of the work to be performed, technical approach, scientific and technical innovation, impact on greenhouse gas sequestration, potential for completing the work as specified in the PRDA, cost reasonableness, the probable cost to the Government, and ranking with competing offerors.

B. Award will be made to that responsible offeror(s), whose offer(s), conforming to this PRDA, is (are) considered most advantageous to the Government, considering the Evaluation Criteria in this Section M.

C. The Government may award a contract on the basis of initial offers received, without discussions. Therefore, each initial offer should contain the offeror's best terms from cost or price and technical standpoint.

M.003b(S) OVERALL RELATIVE IMPORTANCE OF EVALUATION CRITERIA (APR 1984)

The Technical Proposal is of greater importance than the Cost Proposal. However, if after evaluation of the Technical and Cost Proposals, two or more competing overall proposals are substantially equal in technical ranking, evaluated probable cost to the Government may be the deciding factors for selection, depending on whether the most acceptable overall proposal (excluding cost consideration) is determined to be worth the cost differential, if any. The Offer and Other Documents Proposal is to be evaluated for adequacy and compliance with the solicitation.

M.004a(S) EVALUATION CRITERIA (R) (APR 1984)

A. Technical Criteria. Technical aspects of proposals will be evaluated in accordance with the following criteria, which are listed in descending order of importance.

1. SCIENTIFIC/TECHNICAL INNOVATION

The extent to which the proposed work moves beyond the current state-of-the-art, using path-breaking novel, “revolutionary” concepts. Novelty and uniqueness of the proposed concept or application of the proposed concept. The possibility of a science or engineering breakthrough. Readily distinguishable approach from past and current practice and investigations.

Significant scientific and/or technically challenging concepts. The extent to which the application of the proposed concept would reduce emissions below those resulting from improvements or advances in system cycle efficiencies; provides for reuse or production of valuable byproducts; or provides innovative long-term storage or disposal of greenhouse gases.

2. IMPACT

The potential impact in terms of applicability to a large number of sites and quantity (tons) of greenhouse gases that would be recovered or sequestered, and the feasibility of the proposed concept for the development of path-breaking, less costly means to addressing greenhouse gas emissions. If fundamental scientific knowledge and understanding is proposed, the extent to which the knowledge can serve as a basis for the development of path-breaking technologies to reduce greenhouse gas emissions. Potential cost reductions.

3. TECHNICAL APPROACH AND UNDERSTANDING

The manner in which the offeror proposes to accomplish the work as evidenced by the quality, conciseness, and completeness of the proposal, including identification of anticipated problems and proposed solutions. The soundness and level of adequacy of the proposed work to show progress toward proving the feasibility of the concept. The degree to which the objectives of the preceding phase were met at the time that the current application was made. Clarity of the discussion of the technical basis for the proposed work including discussions on relevant technical issues, existing technical barriers, and pertinent research past and current. Technology effectively related to the PRDA objectives.

4. QUALIFICATION OF ORGANIZATION AND KEY PERSONNEL

The qualifications and pertinent experience of the Principal Investigators (PI), other key staff, and consultants, if any. The qualifications of any proposed U.S. industrial partner in regard to the capability to demonstrate successful technologies at large scale. The rationale for and corporate commitment to any teaming arrangement. Availability and time commitments of proposed personnel.

5. FACILITIES

Type, quality, and availability of the proposed equipment, materials, and facilities. Adequacy of the proposed facilities to conduct and support laboratory/bench scale testing, prototype development, and field testing activities. Justification for purchase or lease of facilities, equipment, or materials.

B. Relative Ranking of Technical Criteria. The evaluation of the technical proposal will be conducted using preestablished weights to determine the relative merits of an offeror's proposal in accordance with the technical evaluation criteria.

Criterion 1 is worth 35 percent, Criterion 2 is worth 25 percent, Criterion 3 is worth 20 percent, Criterion 4 is worth 15 percent, and Criterion 5 is worth 5 percent.

C. Cost Criteria. The costs proposed will be evaluated in accordance with the following criteria:

1. Reasonableness and appropriateness of cost.

2. Evaluated probable cost to the Government.

Selection of an offeror for award may involve a determination as to whether an otherwise technically superior proposal is worth any additional associated cost.

D. Program Policy Factors. Program policy factors are those factors that are not indicative of the proposer's individual merit, but are relevant and essential to the process of choosing which proposal(s) will best achieve the program goals. The following program policy factors shall be considered by the Selection Official in the selection process.

1. It may be desirable to select a project(s) for award that can make a substantial contribution to the development of technological options for greenhouse gas emissions reduction.

2. It may be desirable to select a project(s) for award which complement or enhance DOE's programmatic objectives.

3. It may be desirable to select a project(s) for award that represents a diversity of technology concepts and applications, as well as technical approaches.

4. It may be desirable to select a project(s) for award of less technical merit than another project(s), if such a selection will optimize use of available funds by allowing more projects to be supported while not being detrimental to the overall objectives of the program.

5. It may be desirable to select a project(s) for award of less technical merit than another project(s), if such a selection will improve the participation of small businesses.